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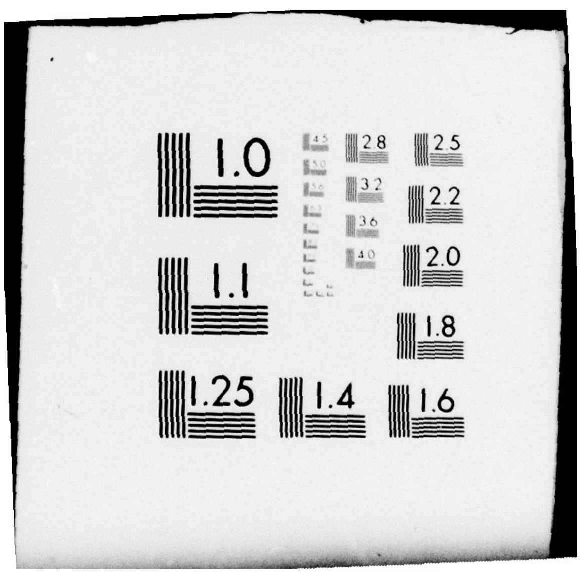
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TECOM PROJECT NO.7-CO-RD5-TT1-016

USATTC REPORT NO. 790102

METHODOLOGY INVESTIGATION

FINAL REPORT

EXPOSURE/PERFORMANCE TESTS OF SELECTED MATERIEL ITEMS

By

George F. Downs
Robert J. Gorak

JANUARY 1979

UNITED STATES ARMY TROPIC TEST CENTER
APO MIAMI 34004

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

USATTC conducted a methodology investigation in the Canal Zone from July 1973 to April 1975 to study the relationships among performance of materiel, exposure, and materials deterioration. Representative items of Army materiel were selected, exposed in different modes in the humid tropics, and performance tested at regular intervals.

Objectives were to learn how and when to measure performance, to relate the performance measures to materiel deterioration, and to learn how and when to Cont'

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apply nondestructive test (NDT) techniques.

The pallet and tarpaulin-forest storage mode provided the most severe environment. Use of this storage mode in tropic surveillance tests will uncover materiel design weaknesses more rapidly than other common long-term storage modes. In general, exterior visible evidence of material degradation should not be used for item performance predictions. Test items exposed in the humid tropics should be performance tested and fully disassembled and examined to determine the full extent of tropic deterioration. Further studies are required to investigate techniques for quantifying the severity of microbial attack and distinguishing between detructive and nondestructive growth.

Meaningful application of NDT techniques to test items during tropic surveillance testing requires further refinement. An investigation should be undertaken to examine state-of-the-art NDT techniques for application to tropic testing.

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FOREWORD

This study was conducted in the Panama Canal Zone as a Methodology Investigation of the United States Army Tropic Test Center under the guidance of Dr. D. A. Dobbins, former Chief, Technical Division, USATTC; and completed under Adam A. Rula, Chief, Materiel Test Division.

SECTION 1. SUMMARY

1.1 BACKGROUND

Static tropic surveillance testing has been conducted in the Canal Zone for many years. These long-term tests are conducted to determine adverse tropic storage effects on the test items. Frequently test sponsors have relied only on visual indicators as evidence of deterioration of test item performance over the exposure period.

Although there is an abundance of information on the visual and tensile strength changes of basic materials, very little work has been done to relate tropic exposure to the performance of materiel items. Insufficient attention has been paid to the selection of the storage mode for static tropic tests. Proper selection of available simulated combat storage conditions can result in the identification of the most severe, yet natural, exposure mode of test items that allows shortening test duration.

A better understanding of the relationships among exposure conditions, material deterioration and performance of materiel items is required.

1.2 OBJECTIVES

The objectives of the methodology investigation were the following:

a. To learn how and when to measure performance of test items on static tropic exposure and to relate performance measures to corrosion and other visible evidence of degradation.

b. To learn how and when to apply nondestructive test instrumentation and techniques to intact test items during static tropic surveillance tests.

1.3 SUMMARY OF PROCEDURES

Representative items of materiel were selected and exposed to ambient conditions in the humid tropics at eight test sites. Control items were stored on shelves in a dark, air-conditioned room. At regular intervals, the test items were examined for corrosion and other visible evidence of deterioration and were performance tested.

Bases for selection of items included measurable performance characteristics, hypothesized susceptibility to tropic deterioration, and common Army usage. The following items were included: tactical radios, batteries, automotive V-belts and roller bearings, POL

products, windshield wiper motors and blades, timers, plastic films, and practice rockets.

The test sites selected were those that showed different deterioration patterns under similar climatic conditions in a previous investigation[16]. The exposure modes of the test items were shed storage at open sites (Shed-Open), shed storage under forest canopy (Shed-Forest), pallet and tarpaulin storage at open sites (P/T-Open), and pallet and tarpaulin storage under the forest canopy (P/T-Forest). The exposure modes were selected to be representative of long-term combat storage conditions.

1.4 SUMMARY OF RESULTS

Significant deterioration in performance of materiel items studied in the investigation was most apparent for items exposed in the pallet and tarpaulin-forest exposure mode. Significant deterioration was present as early as after 2 months of exposure for some items; however, most items required at least 6 months of exposure for significant deterioration to be discernable.

Corrosion was the primary deteriorative agent for material in all the exposure modes studied in the investigation. Corrosion was most rapid and severe in the pallet and tarpaulin-forest exposure mode as exemplified by the extensive corrosion on the automotive roller bearings which were unserviceable after 2 months of exposure in spite of their being wrapped in a corrosion-inhibiting paper.

There was no evidence that microbial growth or insect infestation were related directly to material or performance deterioration of the items exposed to the humid tropic environment. However, it was evident that they indirectly contributed to the corrosive process by causing the deterioration or, in some cases, the total destruction of the boxes in which the test items were packaged.

Exterior item deterioration from tropic exposure does not assure that item performance has degraded nor does the lack of exterior deterioration assure the absence of performance degradation. For example, windshield wiper motors exhibited severe corrosion and blistering and peeling of paint after 6 months of exposure at the Coco Solo Mangrove test site; yet they continued to perform equally as well as those of the control site even after an additional year of tropic exposure. At the other extreme, 81 percent of practice rocket fuzes which exhibited moderate to severe interior corrosion upon disassembly, had no corrosion present on their outer surfaces. Two nonfunctional fuzes, in which springs had split into two parts because of corrosion, had only minor corrosion on their outer surfaces.

Although some tropic deteriorative effects were identified or suspected as a result of radiography of the practice rockets, the majority of internal fuze parts exhibiting moderate to severe corrosion were not identified positively by this nondestructive testing technique.

1.5 ANALYSIS

Statistical variations in the performance of the control materiel items were documented and used as baselines in the evaluation of the performance of materiel items exposed to the humid tropic environment. Analysis of the performance data showed that the severity of the degradation in performance of items exposed in the pallet and tarpaulin-forest mode was greater or at least equal to that of the other exposure modes studied in the investigation.

The performance data of tropic-exposed materiel items were correlated with the presence and severity of corrosion and other visible evidence of degradation. Analyses of these data showed that, in general, observations of material deterioration were poor predictors of item performance.

1.6 CONCLUSIONS

- The pallet and tarpaulin-forest storage mode provides a severe environment that will uncover design weaknesses of materiel items susceptible to corrosion more rapidly than will other common field storage modes in inland humid tropic areas, and thus will shorten the materiel acquisition cycle.

- In general, exterior corrosion and other visible evidence of degradation should not be used for item performance predictions.

- Meaningful application of nondestructive test techniques to intact test items during static tropic surveillance testing requires further investigation.

1.7 RECOMMENDATIONS

- The pallet and tarpaulin-forest storage mode should be considered when choosing an exposure mode for the tropic storage phase of tests. A minimum of 6 months of tropic exposure is recommended.

- Tropic development and surveillance test items should be performance tested and fully disassembled, examined, and, if warranted, tested for structural and/or chemical intergrity to determine the full extent of materiel deterioration in a humid tropic environment.

- An investigation should be undertaken to examine state-of-the-art

nondestructive test techniques for application to tropic development and surveillance tests.

•An investigation should be undertaken to study available microbial coverage/penetration measurement techniques for quantifying the severity of microbial attack on the integrity of materials and distinguishing between destructive and nondestructive growth.

SECTION 2. DETAILS OF INVESTIGATION

2.1 EXPOSURE MODES AND TEST SITES

Exposure modes used in this investigation were shed storage at open and forest sites and pallet and tarpaulin storage at open and forest sites. A total of nine sites were chosen, including a laboratory control site. These are summarized in table 1 and their locations are shown in figure 1. They were chosen to represent a range of severity known from the results of previous investigations. The important characteristics of the sites for each mode are discussed below.

- Shed Storage--Open

Coco Solo Petroleum, Oils and Lubricants Area. This area has been used for development tests of collapsible fuel tanks and test methodology investigations[1, 4, 12, 22, 23]. The exposure site was located in a grassland surrounded by forest (at a distance of 150-300 meters), and consisted of a 20-foot (6.1m) square, open-sided shed with a corrugated metal roof (figure 2). Samples were exposed on uncovered pallets in the center of the shed.

Fort Gulick. This area has been used for storage of munitions components and accessories for a number of years. The chosen site was similar to a nearby site which was used in a previous materials exposure project[16]. Although not under a jungle canopy, the exposure site was surrounded at a distance of about 5 meters by immature forest. The site was located about 500 meters from Gatun Lake and consisted of an open-sided shed with a concrete floor and a bench in the center (figure 3). Heavy samples were exposed on the floor and lighter samples on the bench.

Fort Clayton General Purpose Test Area (Chiva Chiva Antenna Farm). The exposure site in this area was one that had been used in a previous test methodology investigation[16] as well as in several exposure tests. The site was located in a large open field and consisted of a 20-foot (6.1m) square open-sided shed with dirt floor and corrugated roof (figure 4). The samples were exposed without cover on pallets in the center of the shed.

- Shed Storage--Forest

Fort Sherman Forest (Skunk Hollow). This area is located on the Atlantic slope of the Isthmus. The selected exposure site was about one kilometer from the Caribbean Sea.

The site was located in a tropical moist forest and has been used

Table 1. Summary of Environmental Characteristics at Exposure Sites

Site	Coco Solo Open	Ft Gulick Open	Chiva Chiva Open	Ft Sherman Forest	Gamboa A Forest	Ft Sherman Open	Coco Solo Mangrove	Gamboa B Forest
Site Coordinates	248368	247305	563979	146312	381125	148348	233359	364146
Vegetation								
Life Zone **	TMF	TMF	TMF	TMF	TMF	TMF	TMF	TPWF
Association	grass-land	grass-land	grass-land	secondary	nearing mature	grass-land	mature	mature
No. of Stems/hectare	*	*	*	771	1065	*	872	NA
Stem Dimensions:								
Mean Diameter, cm	*	*	*	5.9	7.8	*	14.1	NA
Mean Height, cm	*	*	*	8.5	11.2	*	11.4	NA
Soils								
Texture Class, USDA	clay loam	NA	sandy clav loam	loam	silt loam	sandy loam	sandy loam	silt loam
Mechanical Analysis:								
Sand, percent	24.4	NA	47.5	41.4	23.4	65.4	76.0	NA
Silt, percent	36.0	NA	22.1	33.0	51.8	19.0	7.0	NA
Clay, percent	39.6	NA	30.4	25.6	24.8	15.6	17.0	NA
Topography								
Landform	open alluvial plain	open plain	open plain	rolling hills	rolling hills	open alluvial plain	(A)	(B)
Slope Char:								
Slope, percent	0	0	2.5	3.5	0.5	0	0	NA
Azimuth, degree	*	*	135	275	270	*	*	NA

LEGEND:
NA = Not available
* = Not applicable
TMF = Tropical Moist Forest
TPWF = Tropical Premontane Wet Forest
(A) = Tidal mud flat of low coastal plain
(B) = Level section of the side of a low rugged hill
** = Vegetation is classified according to the Holdridge Life Zone classification scheme

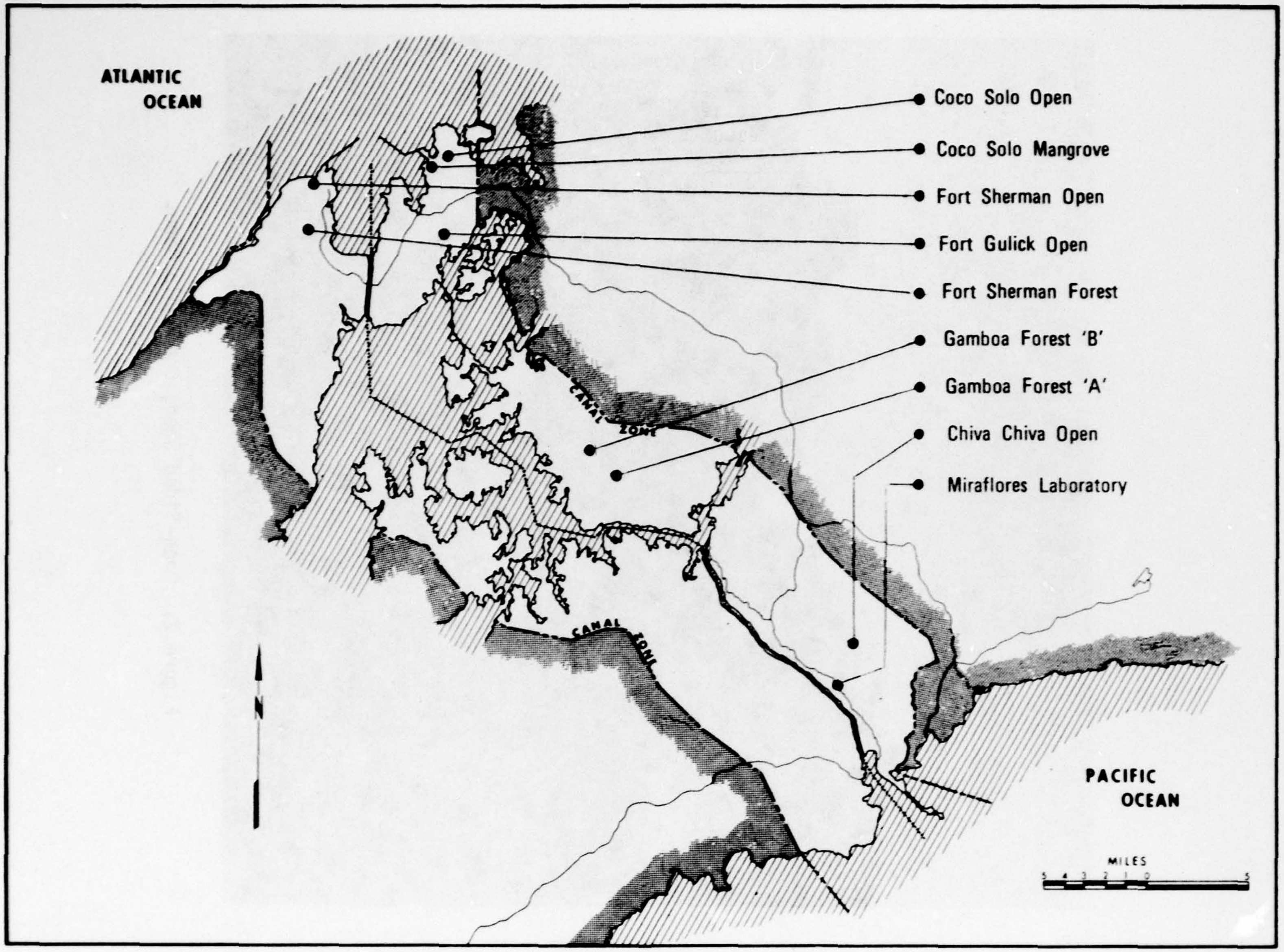

Figure 1. Location of Exposure Sites in the Canal Zone.

Figure 2. Open-Sided Shed, Coco Solo Open.

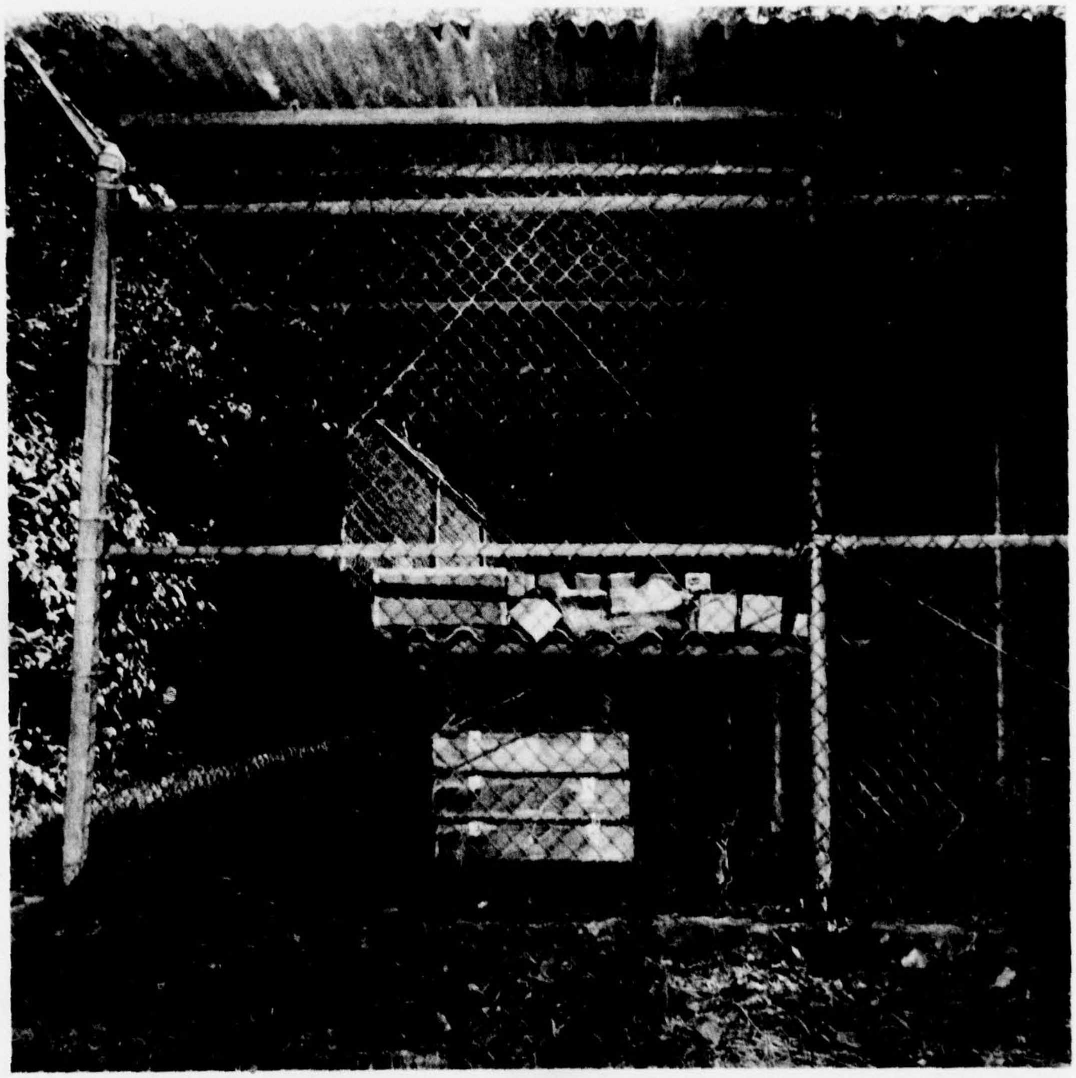

Figure 3. Open-Sided Shed, Fort Gulick Open.

Figure 4. Open-Sided Shed, Chiva Chiva Open.

for over 25 years by various groups interested in tropic deterioration in a forest environment. All items were exposed in a shed with corrugated metal walls and a dirt floor (figure 5). The bottom and top foot (30cm) of wall material had been replaced by expanded metal of about 1/2-inch (13mm) mesh for ventilation. The forest canopy was relatively dense, making the inside of the shed very dark when the door was closed. Heavy samples were stored on pallets, and lighter ones on shelves.

Gamboa Forest "A." This area was also used in a previous methodology investigation[16]. The chosen site in the area was located in a densely-canopied, tropical moist forest with little undergrowth on the forest floor. A stream flowed through the forest at a distance of about 25 meters from the site. The site consisted of a 20-foot (6.1m) square open-sided shed with a dirt floor and corrugated roof (figure 6). The samples were exposed on uncovered pallets in the center of the shed.

- Pallet and Tarpaulin - Open

Fort Sherman Open. This open field area has been used for many years for studies of actinic deterioration. The exposure site in this area was located 500 meters from the Caribbean Sea. The water table varied from one foot (30cm) to ground level at this site. Samples were exposed on pallets, covered by a tarpaulin, inside a chain-link fenced cage (figure 7).

- Pallet and Tarpaulin - Forest

Coco Solo Mangrove. This swampy, forested area has been found to be the most corrosive to steel of any area in the Canal Zone. The trees in this forest are predominantly <u>Avicennia nitida</u> and are heavily overgrown with moss and orchid plants. The exposure site in this area was located under the mangrove canopy and consisted of a chain-link fenced cage. The samples were exposed on pallets, covered by a tarpaulin (figure 8). The water level in the swamp varied from 8-12 inches (20-30 cm) below the samples, and was predominantly seawater except during and shortly after rains, when it was brackish.

Gamboa Forest "B." The exposure site in this area was located 2.7 kilometers from the Gamboa Forest "A" site, in a tropical premontane wet forest (i.e., higher altitude, wetter conditions, different mix of vegetation in contrast to the Gamboa Forest "A" site). A stream flowed past the site at a distance of about 15 meters. The site consisted of a cage made of chain-link fencing. Samples were exposed on pallets, covered by a tarpaulin (figure 9).

- Control Storage

Miraflores Laboratory was the control site. Samples were stored on shelves in a dark, air-conditioned room.

Figure 5. Ventilated Shed, Fort Sherman Forest.

Figure 6. Open-Sided Shed, Gamboa Forest 'A'.

Figure 7. Pallet/Tarpaulin, Fort Sherman Open.

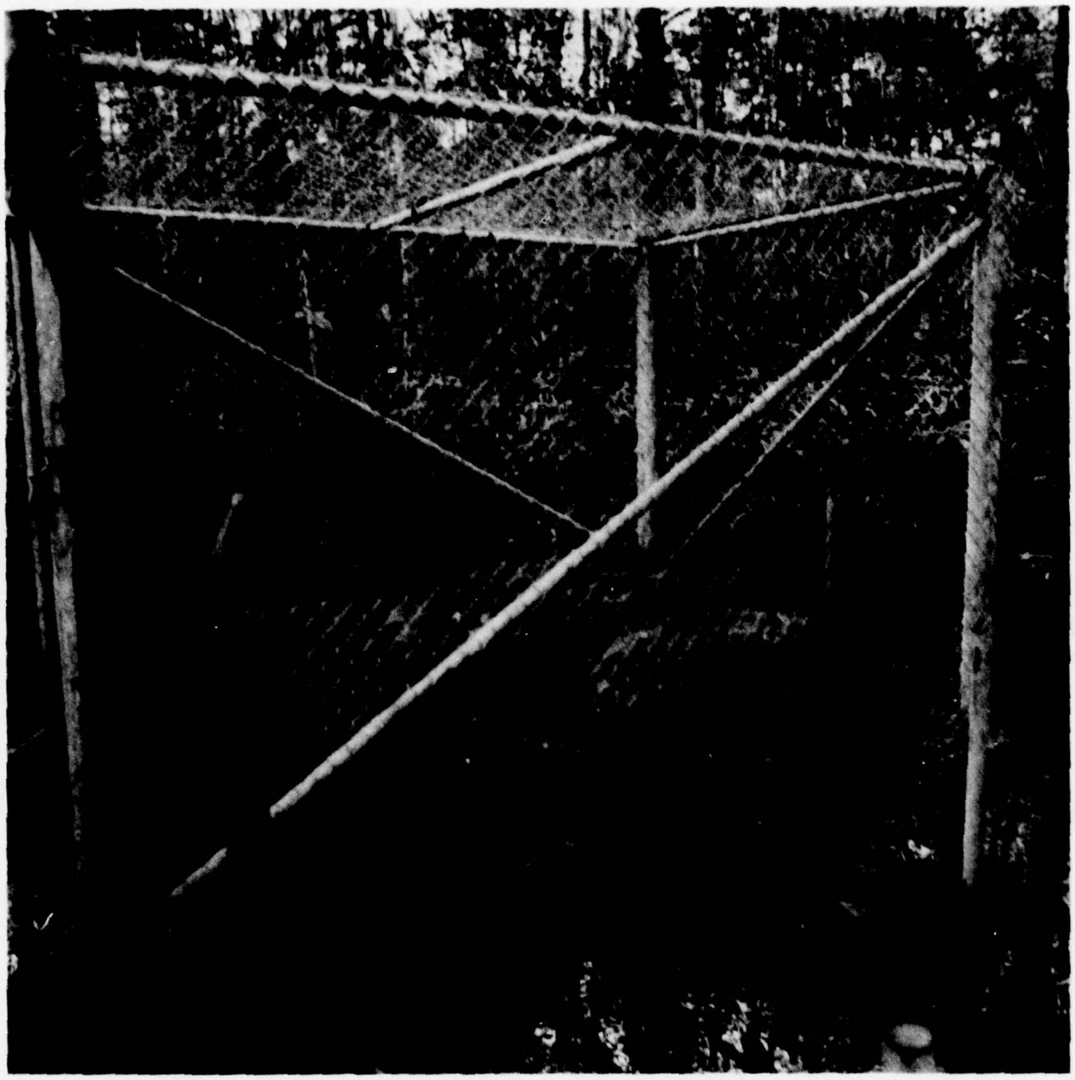

Figure 8. Pallet/Tarpaulin, Coco Solo Mangrove Forest.

Figure 9. Pallet/Tarpaulin, Gamboa Forest 'B'.

2.2 ITEM DESCRIPTION AND PERFORMANCE TEST PROCEDURE

The materiel items selected for the investigation, the number of retrievals, the number of items per retrieval, and the performance measures used are summarized in table 2. The items were placed on exposure and periodically examined and performance tested in accordance with the Retrieval/Performance Testing Schedule shown in table 3. Item characteristics and performance test procedures are discussed below.

2.2.1 Tactical Radios (AN/PRT-4A, AN/PRR-9).

The AN/PRT-4A is the squad radio transmitter, designed for short-range infantry use. It is handheld and contains its own battery (BA-399/U). It is mounted in an aluminum/magnesium case painted OD. The AN/PRR-9 is the squad radio receiver and is the companion to the AN/PRT-4A. The radio receiver, housing its own battery (BA-505/U), can be either handheld or clipped to the helmet liner or helmet. The major visible portion of the receiver consists of the speaker horn, which is made of a plastic material painted OD. The electronic components are housed in a rectangular metal tube. An accessory earphone is included for silent listening.

Five transmitters and 5 receivers were exposed at each site, including the Laboratory Control site. Approximately after every 9 weeks of exposure, the transmitters and receivers were visually inspected, retrieved, performance tested, and returned to their original exposure site. Total exposure time at each site was approximately 17 months during which time eight retrievals were made.

The sequence of testing of transmitter performance at the retrievals was as follows:

a. Measure and record the radiated power received by a standard antenna at a distance of 30 meters.

b. Monitor spurious outputs (e.g., harmonics) from the transmitter.

c. Monitor and record power consumption.

d. Measure and record output power to antenna, measured as voltage across a 72-ohm dummy load.

The sequence of testing of receiver performance at the retrievals was as follows:

a. Measure and record power comsumption.

b. Monitor and record audio noise level.

Table 2. Test Items

Item	Federal Stock Number	Initial Quantity per Site	No. of Items per Retrieval per Site	No. of Retrievals per Site	Performance Measures
Squad Radio:					
Transmitter AN/PRT-4A	5820-133-8980	5	5	8	Radiated power, power consumption, output power to antenna.
Receiver AN/PRR-9	5820-069-8931	5	5	8	Power consumption, audio noise level, squelch break sensitivity, quieting sensitivity.
Batteries:					
BA-30	6135-210-1020	60	10	6	Available voltage, electrical capacity
BA-399/U	6135-926-0845	30	5	6	Available voltage, electrical capacity
BA-505/U	6135-926-0844	30	5	6	Available voltage, electrical capacity
V-Belts	3030-832-5671	90	15	5	Fatigue (test to destruction)
Automotive Roller Bearings	2530-887-1341	60	10	6	Visible corrosion per Fed. Spec. FF-B-187a.
POL Products (1 gal. cans of gasoline and diesel)	8110-178-8282	30	5	6	Gas chromatography
Windshield Wiper Motor	2540-678-1340	30	5-30	8	Lifting ability
Windshield Wiper Blade	2540-050-0813	30	5	6	Wiping ability
Interval Timer	6645-547-4467	9	9	8	Readability, timing.
Barrier Material (Plastic Bags)	8135-068-9466	30	5	6	Tensile strength, water vapor transmission rate
Practice Rocket, 3.5-Inch	1340-028-6092 H601	9	9	1	Radiographic examination

Table 3. Retrieval/Performance Testing Schedule

	9 Jul 73	30 Jul 73	20 Aug 73	10 Sep 73	1 Oct 73	22 Oct 73	12 Nov 73	3 Dec 73	22 Dec 73	14 Jan 74	4 Feb 74	25 Feb 74	18 Mar 74	8 Apr 74	29 Apr 74	20 May 74	1 Jun 74	1 Jul 74	22 Jul 74	12 Aug 74	2 Sep 74	11 Nov 74	3 Dec 74	23 Dec 74	21 Feb 75	24 Mar 75	23 Apr 75
Miraflores Lab	X			C			C			C			C			C			C			C			C		
Ft Sherman Open	X			C			C			C			C			C			C			C			C		
Ft Sherman Forest	X			C			C			C			C			C			C			C			C		
Coco Solo Open		X			C			C			C			C			C			C			C			C	
Coco Solo Mangrove		X			C			C			C			C			C			C			C			C	
Ft Gulick Open		X			C			C			C			C			C			C			C			C	
Chiva Chiva Open			X			C			C			C			C			C			C			C			C
Gamboa Forest "A"			X			C			C			C			C			C			C			C			C
Gamboa Forest "B"			X			C			C			C			C			C			C			C			C

Legend
X Initial exposure
C Sample retrieval/performance testing

c. Measure and record squelch break sensitivity.

d. Measure and record sensitivity for 10 db quieting.

The above performance parameters were measured before and after alignment of the transmitters and receivers. Alignment was performed to detect variation in test items performance due only to channel misalignment, i.e., drift. Alignment of the test items was accomplished using the ID-1189/PR Channel Alignment Indicator in accordance with TM 11-6625-937-12[21].

A test fixture, standard dummy and loop antennas, an audio load adapter and battery adapter cord were locally fabricated in order to reduce the number of variables being observed. A regulated power supply was also used in place of the normal battery to eliminate errors due to changing battery voltage. Additional equipment used included the following:

Spectrum Analyzer, HP 8551B w/display
Oscilloscope, HP 180
Signal Generator, Marconi 1066/B6
Current Meter, TS-352
Voltmeter, Simpson 269
2-Way Communication (radio or telephone)

2.2.2 Batteries (BA-30, BA-399/U, BA-505/U).

The BA-30 battery is a common 1.5-volt flashlight cell (size D) housed in a steel jacket. The BA-399/U is a 15-volt battery composed of 12 "pancake" cells, connected in series and mounted in a rectangular cardboard box. It fits into the battery case of the AN/PRT-4A transmitter, for which it was designed. The BA-505/U is a 6-volt battery composed of four size "N" carbon-zinc cells mounted in series in a cardboard-lined aluminum tube. It is used primarily as the power source for the AN/PRR-9 radio receiver.

Sixty BA-30 batteries, 30 BA-399 batteries, and 30 BA-505 batteries were exposed at each site including the Laboratory Control site. Ten BA-30, five BA-399, and five BA-505 batteries were retrieved from each exposure site every 9 weeks until the last batch of batteries were retrieved at the end of the 54th week of exposure. At each retrieval, the retrieved batteries were visually examined for surface corrosion, fungal growth, and evidence of internal defects. The batteries were tested then for available voltage and discharge time (electrical capacity).

The discharge test for the BA-30 battery was similar to the specification test spelled out in MIL-B-18/9B[9] except that the battery was subjected to a continuous 5-ohm load rather than an intermittent load of 6.67 ohms. During this test, the battery voltage was recorded

every 6 minutes to a test-end voltage of 0.93 volt. Failure times were interpolated if necessary and were read to ± 2 minutes. A fixture for holding 20 batteries and their respective load resistors was locally fabricated and assembled with a 24-position rotary switch for semiautomatic voltage measuring on a chart recorder.

The discharge test for the BA-399 batteries was performed in accordance with the discharge test design of MIL-B-18/250 (EL)[10]. The test design required alternate discharging through a resistance of 100 ohms for 2 minutes, then remaining on open circuit for 28 minutes, to a test-end voltage of 10.0 volts. Ten batteries were tested simultaneously on a locally fabricated test fixture. Voltage readings were taken every 30 minutes.

The discharge test for the BA-505 batteries was performed in accordance with MIL-B-18/251 (EL)[11]. Each battery was discharged continuously through a load of 400 ohms to a test-end voltage of 4.0 volts. Fifteen batteries were tested simultaneously using the same equipment and test fixture employed for the discharge test of the BA-30 batteries. Voltage readings for each battery were taken every 6 minutes and the time for each battery to drop to 4.0 volts was recorded.

2.2.3 <u>V-Belts</u>.

The V-belts are approximately 0.380 inches (0.97cm) wide and 36 inches (91cm) long and are reinforced with a cellulosic cord which is subject to shrinkage in extremely humid conditions. The belts are used in the M151 1/4-ton tactical wheeled vehicle.

Thirty V-belt sets, containing three belts each, were exposed at each of the nine exposure sites. Five V-belt sets were retrieved from each site every 9 weeks. These belts were measured for shrinkage and visually inspected for microbial growth on their sidewalls and inner and outer circumferences. Representative samples from each site were subjected to a destructive fatigue test.

The fatigue test was similar to the one specified in MIL-B11040C[7]; however, the specified driving and idler pulleys were operated at 4900 rpm under a load of 13 horsepower (9.69kW) and a no-load tension of 132 lbs (59.9kg). In addition, prior to testing the belts were run-in for 10 minutes under a no-horsepower load and a no-load tension of 172 lbs (78.0kg) to "get the stretch out." These tensions and power load were greater (by a factor of two) than those specified by MIL-B-11040C and were selected to reduce test time but still allow detection of storage effects on belt serviceability.

2.2.4 Automotive Roller Bearings.

These bearings are contained in the replacement wheel bearing kit for the M151 1/4-ton tactical wheeled vehicle. The complete kit consists of two tapered roller bearings, a spindle nut, a washer, and a cotter pin. The two bearings are identical and have the following dimensions: outside diameter 73.0mm, inside diameter 42.9mm, and thickness 20.6mm. The bearings are wrapped in a vapor-type corrosion inhibiting paper and are lightly oiled.

Thirty wheel bearing kits were exposed at each of the exposure sites. Five kits were retrieved from each site every 9 weeks. The last retrieval was made at the end of the 54th week of exposure. At the time of retrieval the bearings were examined for corrosion. Bearing serviceability was judged first on condition of running surfaces and rollers; and second on bore, outside diameter and faces. Three categories of serviceability were used: unserviceable, serviceable after cleaning, and serviceable without qualification. Any visible corrosion on running surfaces or rollers rendered the bearing unserviceable, in accordance with Federal Specification FF-B-187a[3]. Any visible corrosion on the outside diameter, bore, or faces rendered the bearing serviceable after cleaning. If no corrosion was discernible, the bearing was judged to be serviceable without qualification.

2.2.5 POL Products (Gasoline and Diesel).

The POL products were standard motor pool issue gasoline and diesel fuel, packaged in 1-gallon rectangular screw-cap, tin-plated cans. Thirty cans of each POL product were placed on exposure at each site at the beginning of the investigation. Every 9 weeks thereafter, five cans of each POL product were retrieved from each site.

At each retrieval, the cans were visually examined for rust, product leakage and internal contamination by water. Samples of the POL products were examined for microbial growth and were tested for trace amounts of dissolved water by shaking with an indicating desiccant. Additionally, the fuel samples were analyzed for composition by gas chromatography. Compositional analyses were accomplished using a Model 7620A Hewlett-Packard gas chromatograph, equipped with either a thermal conductivity detector or a dual flame ionization detector and a digital integrator. Sampling was effected by thoroughly mixing the POL sample, withdrawing the required sample size from the upper 2-inch (5cm) level, and injecting it directly into the gas chromatograph. Gas chromatographic parameters are shown in table 4.

Table 4. Gas Chromatographic Parameters

	Gasoline Analysis	Diesel Analysis
Detector	Thermal Conductivity/200ma	Flame Ionization
Detector Temp	250°C	300°C
Flow Rates	Helium: 14ml/min	Helium: 10ml/min Hydrogen: 45ml/min Air: 280ml/min
Injection Temp	250°C	275°C
Sample Size	1.0 µl	0.2 µl
Column	10% Carbowax 20 M, 8' x 1/8" (in series with) 10% Apieson L, 6' x 1/8" O.D. stainless steel; both on 60/80 mesh Chromosorb.	10% SP-2100, 6'x 1/8" O.D. stainless steel on 100/120 mesh Supelcoport

2.2.6 Windshield Wiper Motors.

These motors are a "universal" military type used on the M151 1/4-ton tactical wheeled vehicle. They can be operated by either vacuum or compressed air.

Thirty motors were exposed at each site for a period of 20 months during which time eight retrievals of the test items were made. Retrieval intervals were approximately 9 weeks for the first six retrievals and 16 weeks for the last two retrievals. At the first retrieval five motors from each site were retrieved, visually inspected, tested, and replaced on exposure. At the second retrieval the initial five plus five untested motors were retrieved, visually inspected, tested and replaced. At each successive retrieval, five additional motors were added to the retrieved lot until the sixth retrieval, at which time all motors were retrieved and tested. All test items were retrieved and tested at the seventh and eighth retrievals.

At each retrieval the motors were visually inspected for fungal growth on the motor, insect infestation, corrosion of shaft bushing (connection point of the wiper arm) and peeling and blistering of paint. Since the motors are operated by intake manifold vacuum on the M151, they were tested at each retrieval using vacuum as their performance measure. The test consisted of attaching the standard wiper arm to the motor in a horizontal position. A 250-gram weight was then attached to the arm and the vacuum was gradually increased until the motor lifted the weight. The vacuum at that point was recorded and the test was repeated five times for each motor at each retrieval.

2.2.7 Windshield Wiper Blades.

These blades are used on the M151 1/4-ton tactical vehicle. They are a straight-back design with several layers of thin rubber sheet laid together for the wiping edge. Thirty blades were exposed at each of the nine exposure sites. Five blades were retrieved from each site every 9 weeks and visually inspected for corrosion, blistering of paint, and fungal growth. The retrieved blades were then attached to the arm of a standard wiper motor on a windshield assembly and performance tested with the criterion that the blade must wipe, clean and streak free, a suspension of clay soil in water from the windshield in 20 strokes or fewer.

2.2.8 Interval Timers.

These spring-wound internal timers are capable of being set to 30 minutes or less. The timers control an internal electric switch which is closed when the timer is set and opened after the selected time interval has elapsed.

Eighty-five timers were placed on exposure - 12 timers at the Coco Solo Mangrove site, 10 at the Laboratory Control site and 9 at each of the remaining seven sites. Retrieval intervals were approximately 9 weeks for the first six retrievals and 16 weeks for the last two retrievals. At each retrieval, all exposed timers were inspected and performance tested. The timers were visually examined for readability, insect infestation, and corrosion of the timer case. Timers were performance tested by setting them for 30 minutes and measuring the actual time the timer ran. The test was repeated five times for each timer at each retrieval. After testing, each timer was returned to its original exposure site.

2.2.9 Barrier Material (Plastic Bags).

This material is a low density polyethylene film, specified by Federal Specification L-P-378C[6], type I, class 1, finish 1. Thirty plastic bags of this material were placed at each exposure site. The plastic bags had an inside area of 200 square inches (1290cm^2). A paper container holding 100 grams of dried desiccant was placed inside each plastic bag to determine water uptake during exposure.

Five plastic bags with desiccant were retrieved from each site every 9 weeks. The retrieved bags were visually examined for fungus and algae growth, water spots and mud - the latter two providing evidence of prior exterior wetness. The bags were weighed upon retrieval to determine the weight gain from water vapor absorption. Representative samples were tested for tensile strength and water vapor transmission rate and the measured results were compared with those of unexposed material.

2.2.10 Practice Rockets, 3.5-Inch.

These rockets were rendered totally inert by removing the propellant and igniter; however, the fuze was left intact.

Three wooden boxes, each containing three rockets, were exposed at each of the field exposure sites for 54 weeks. The rockets were periodically examined radiographically in the field. The principal area of interest was the fuze area which is located in the center of the rocket. The fuze contains several small springs, plungers and stops which are seen readily in an X-radiograph. The X-radiographs were examined to determine if parts were in their correct locations, if the springs were collapsed or excessively corroded, and if the rocket had been setback armed. At the end of the 54th week of exposure, the rockets were retrieved. Their fuzes were disassembled in the laboratory and their actual condition was compared to that surmised from radiographic inspection. The following parts of the disassembled fuze were inspected for corrosion: outside surface, safety pin, safety pin spring, outside surface of the plug, inside surface of the plug, setback plunger, setback plunger spring, non-return pin, and non-return pin spring. Each of these items was rated on a scale of zero to 4 as follows:

0 - No visually discernible corrosion.

1 - Minor corrosion: surface change in color or texture but no build-up of corrosion product or pitting.

2 - Moderate corrosion: usually associated with shallow pitting on aluminum and brown rust on galvanized parts.

3 - Severe corrosion: severe pitting or brown rust covering most or all of surface but not leading to part failure.

4 - Corrosion failure: corrosion resulting in fuze part becoming nonfunctional.

2.3 EXPOSURE/PERFORMANCE TEST RESULTS

2.3.1 Tactical Radios (AN/PRT-4A, AN/PRR-9).

At each 9-week retrieval, the radio transmitters were performance tested for radiated power, power consumption, and output power to antenna. The radio receivers were tested for power consumption, audio noise level, squelch break sensitivity, and quieting sensitivity. The test data are summarized in tables 5 and 6 which present the estimates of the mean and standard deviation for the receiver and transmitter performance parameters over the 17 months of exposure.

Table 5. Receiver Performance Data Summary, Means and Standard Deviations (SD) of Performance Parameters

	Before Alignment												After Alignment											
	Input Power (mW)			Audio Noise (db)			Squelch Sensitivity (μV)			Quieting Sensitivity (mW)			Input Power (mW)			Audio Noise (db)			Squelch Sensitivity (μV)			Quieting Sensitivity (μV)		
Site	Mean	SD	No	Mean	SD	No	Mean	SD	No	Mean	SD	No	Mean	SD	No	Mean	SD	No	Mean	SD	No	Mean	SD	No
Miraflores Laboratory	121.9	8.3	34	4.75	0.52	35	3.44	1.18	8	3.48	0.61	12	119.4	4.5	20	4.86	0.44	20	2.93	0.70	15	2.68	0.53	16
Ft Sherman Forest	116.2	9.5	34	3.79	1.14	34	4.42	1.53	9	3.22	0.84	12	113.1	6.4	20	3.83	1.32	20	3.35	1.01	15	2.57	1.08	18
Ft Sherman Open	118.8	8.3	34	4.05	0.86	28	4.00	1.19	7	3.39	0.75	10	114.7	5.6	18	4.34	0.93	15	3.12	0.93	13	2.60	0.80	15
Coco Solo Open	120.4	6.5	34	4.60	0.84	36	4.31	1.25	9	2.99	0.90	16	115.5	4.4	20	4.75	0.59	20	3.05	0.78	18	2.72	0.50	20
Coco Solo Mangrove	115.7	9.8	40	3.92	1.10	38	3.74	1.60	13	2.79	0.70	17	111.5	7.2	25	3.92	1.10	25	3.09	1.07	25	2.60	0.60	25
Ft Gulick Open	116.6	7.5	40	4.55	0.59	37	4.78	1.74	25	3.01	0.69	17	112.2	5.1	25	4.64	0.34	22	3.32	1.10	21	2.68	0.68	22
Chiva Chiva Open	117.7	8.3	40	4.86	0.42	40	4.89	2.13	18	3.53	1.36	19	116.4	4.1	30	4.88	0.29	30	3.89	1.34	28	2.92	1.17	30
Gamboa Forest "A"	112.9	9.9	39	4.43	0.44	39	4.29	1.51	17	3.12	0.97	18	112.1	5.3	29	4.59	0.33	29	3.46	1.00	29	2.50	0.86	29
Gamboa Forest "B"	117.6	8.0	40	4.86	0.38	38	3.81	1.30	16	3.14	0.64	18	116.4	3.4	29	4.90	0.26	28	3.27	1.10	27	2.64	0.60	28

Table 6. Transmitter Performance Data Summary, Means and Standard Deviations (SD) of Performance Parameters

		Before Alignment									After Alignment								
		Input Power (watts)			IF Gain (db)			Antenna Peak-Peak Voltage (volts)			Input Power (watts)			IF Gain (db)			Antenna Peak-Peak Voltage (volts)		
Group	Site	Mean	SD	No	Mean	SD*	No	Mean	SD*	No	Mean	SD	No	Mean	SD*	No	Mean	SD*	No
	Miraflores Laboratory	2.70	0.45	24	62.3	2.54	35	8.3	0.63	30	2.45	0.27	18	63.9	1.15	20	9.0	0.32	19
1	Ft Sherman Forest	2.57	0.29	25	62.8	1.91	35	7.9	0.67	30	2.52	0.22	20	64.1	2.21	20	9.1	0.32	20
	Ft Sherman Open	2.55	0.20	18	61.4	0.90	27	7.9	0.35	20	2.46	0.21	13	62.8	0.88	15	8.9	0.17	15
	Coco Solo Open	2.72	0.25	32	66.2	2.34	36	8.8	0.30	37	2.52	0.22	17	67.7	1.40	17	8.6	0.27	17
2	Coco Solo Mangrove	2.60	0.52	32	65.5	2.83	34	8.2	1.16	37	2.52	0.28	17	68.4	1.96	16	8.5	0.36	17
	Ft Gulick Open	2.56	0.29	32	66.6	5.58	38	8.5	0.64	32	2.47	0.19	20	67.2	1.28	20	8.4	0.39	20
	Chiva Chiva Open	2.58	0.22	32	68.6	1.77	40	8.8	0.55	40	2.42	0.21	30	70.0	1.08	30	9.8	0.45	30
3	Gamboa Forest "A"	2.57	0.30	34	69.6	2.19	39	8.4	0.37	38	2.41	0.19	28	70.3	2.24	28	9.6	0.47	29
	Gamboa Forest "B"	2.47	0.21	23	68.6	1.82	28	8.7	0.40	28	2.41	0.36	18	69.4	1.60	17	9.6	0.29	18

* These values are best estimates under the assumption of a constant mean and are not contaminated by the variance of the systematic errors discussed in the text.

The method of least-squares was used to determine equations of the best-fit linear lines for each set of performance data for the receiver. For each receiver performance parameter, F-ratio tests (alpha = 0.05) were performed comparing the slopes of the lines determined for each exposure site with that determined for the control site. The analysis showed that there was no significant degradation in any of the receiver performance parameters for any of the exposure sites.

Power consumption data for the transmitter was analyzed in the same manner as the receiver performance data. No significant degradation in transmitter power consumption was evident for any of the exposure sites. Analysis of the transmitter radiated power (measured as IF gain) and output power to the antenna (measured as peak-to-peak voltage across a 72-ohm dummy load) showed that there were significant systematic errors (biases) in the data, apparently as a result of improper zeroing of the test instrumentation. The biases are readily apparent among the site groupings shown in table 6. The transmitters at the sites within a particular grouping were retrieved and tested (table 3) in a relatively short span of time (normally within one day). Thus the performance data collected on these transmitters would be expected to show the same systematic errors if instrumentation problems were the cause of the bias. An analysis of the data from the grouped sites showed that there were no significant differences among the sites in any group. Further analysis showed that the standard deviations of the performance parameters from all sites were not increasing with exposure time. In summary, there was no evidence of any degradation in transmitter performance at any of the exposure sites.

At each retrieval the radios were visually examined for external corrosion, blistering of paint, fungal growth, and insect infestation. Corrosion was usually noted on the transmitter's back panel, on battery clips, control shafts, the receiver's earphone jack and around the battery box. Corrosion and paint blistering were most severe at the pallet and tarpaulin-forest exposure sites followed by the pallet and tarpaulin-open exposure site. Apparently the pallet and tarpaulin type of exposure prevents evaporation of diurnal condensation which is then absorbed by the boxes in which the radios were stored. Extreme wetness of the boxes and radios was observed at these sites on several occasions.

Insect infestation was noted at most sites with varying frequency; however, infestation occurred only in significant quantities at the Coco Solo Open site.

Fungal growth was most prevalent at the forest exposure sites and was most severe at the Fort Sherman Forest site. Fungal growth occurred most frequently on the plastic parts, speaker horn, and rubber phone jack gasket of the radio receiver; however, no apparent damage resulted from the growth.

2.3.2 Batteries (BA-30, BA-399/U, BA-505/U).

•Battery, BA-30

Upon retrieval, BA-30 batteries were visually examined for surface corrosion and for evidence of internal defects. They were performance tested for available voltage under load and capacity (time to discharge).

The performance data from the laboratory control batteries were used to establish a baseline for the determination of battery deterioration from tropic exposure. From these data, minimum performance (failure) criteria of 1.25 volts and 3.8 minutes for the battery available voltage and discharge time, respectively, were established.

An analysis of batteries failing to meet the minimum performance criteria (MPC) using the Chi-square test (alpha $\leq$ 0.05) showed that batteries exposed at the Coco Solo Mangrove site exhibited the most severe deterioration with significant deterioration in performance evident after the 6th month of exposure. Significant performance deterioration was also observed at the other sites with the exception of Coco Solo Open. Significant deterioration in performance was observed after 6 months of exposure at Gamboa Forest "B" and Fort Sherman Forest sites, after 8 months at the Chiva Chiva Open, Fort Gulick Open, and Gamboa Forest "A" sites, and after 12 months at the Fort Sherman Open site. A summary of battery performance data is presented in table 7.

Table 7. Number of BA-30 Batteries Failing Performance Criteria as a Function of Exposure Time *

Site	Total Failure Percentage	Exposure Time, Weeks 9	18	27	36	45	54
Coco Solo Mangrove	63	1	0	9	10	9	9
Chiva Chiva Open	43	2	2	2	6	6	8
Gamboa Forest "B"	31	3	1	3	2	5***	**
Fort Gulick Open	28	2	0	1	5	3	6
Fort Sherman Forest	18	3	0	4	4	0	0
Gamboa Forest "A"	17	1	1	0	4	1	3
Fort Sherman Open	12	0	0	1	0	0	6
Coco Solo Open	7	1	0	0	0	0	3
Miraflores Lab	3	0	1	0	0	0	1

* Sixty batteries were initially exposed at each site; every 9 weeks thereafter, 10 batteries from each site were retrieved and tested.
** Data not available.
*** Only five batteries were tested.

Three observation criteria were used in an attempt to relate visual observation of deterioration to performance deterioration. Occurrences of batteries exhibiting (1) any surface corrosion, (2) severe surface corrosion, and (3) evidence of internal defects, i.e., swelling or leakage, were recorded. These were correlated with battery performance determined in accordance with the MPC. The results are shown in the table below. The numbers in the table represent the number of batteries belonging to a tabulated category. For example, 118 batteries whose performance was significantly different from that of the laboratory control batteries, i.e., failed the MPC, exhibited surface corrosion.

Minimum Performance Criteria	Surface Corrosion Yes	Surface Corrosion No	Severe Surface Corrosion Yes	Severe Surface Corrosion No	Internal Defects Yes	Internal Defects No
Fail	118	10	66	62	57	71
Pass	187	165	25	327	73	279

As seen from the table, none of the observation criteria were adequate for predicting battery performance. For example, only 45 percent of the batteries which failed the MPC had evidence of internal defects while 56 percent of the batteries which had evidence of internal defects passed the MPC.

•Battery, BA-399

Following tropic exposure, the BA-399 batteries were examined for corrosion, fungus growth and insect infestation. Battery performance was evaluated in terms of available voltage and electrical capacity (discharge time).

Performance data from the laboratory control batteries were used as baseline data to determine performance deterioration from tropic exposure. From these data, minimum performance criteria (MPC) of 12.9 volts and 20.0 hours for available voltage and discharge time were established. Resulting analysis using the Chi-square test (alpha $\leq$ 0.05) and the MPC showed that the Coco Solo Mangrove site was the most severe to the BA-399 batteries, with significant deterioration being apparent after 4 months of exposure. There was also significant degradation in battery performance at the Fort Sherman Open, Coco Solo Open, and Fort Gulick Open sites; however, significant degradation was apparent only after the 10th or 12th month of exposure. There was no significant degradation in battery performance at the Fort Sherman Forest, Chiva Chiva Open, and Gamboa Forest "A" sites. Sufficient data were not available to evaluate the performance of the batteries at the Gamboa Forest "B" site beyond 8 months of exposure. At that time, no significant degradation in battery performance was apparent. A summary of battery performance data is presented in table 8.

Table 8. Number of BA-399 Batteries Failing Performance Criteria as a Function of Exposure Time *

Site	Total Failure Percentage	Exposure Time, weeks 9	18	27	36	45	54
Coco Solo Mangrove	87	3	5	4	5	5	4
Fort Gulick Open	50	1	3	0	3	3	5
Coco Solo Open	47	2	1	0	3	4	4
Fort Sherman Open	43	0	4	1	1	2	5
Fort Sherman Forest	30	0	1	0	4	3	1
Gamboa Forest "A"	30	3	0	1	1	3	1
Chiva Chiva Open	30	0	0	2	2	4	1
Gamboa Forest "B"	29	0	0	2	3	1***	**
Miraflores Lab	20	**	0	0	2	1	2

* Thirty batteries were initially exposed at each site; every 9 weeks thereafter, five batteries from each site were retrieved and tested.

** Data not available.

*** Only one battery was tested.

Occurrences of corrosion and swelling of the battery were recorded and correlated with battery performance, determined in accordance with the MPC, in an attempt to relate visual observations with performance. The results are shown in the table below. The numbers in the table are the number of batteries belonging to the tabulated category.

Minimum Performance Criteria	Corrosion/Swelling Yes	No
Fail	20	84
Pass	1	126

As with the BA-30 battery, visual observations of corrosion/swelling proved to be unacceptable for predicting battery performance --- observations of corrosion/swelling accounting for only 19 percent of the batteries which failed to meet the MPC. However, corrosion/swelling was a fairly good predictor of catastrophic failure of the BA-399 (catastrophic failure being defined as a battery with an available voltage of zero). Twenty-one batteries failed catastrophically during the investigation --- 18 at the Coco Solo Mangrove site, 2 at the Fort Sherman Open site, and 1 at the Gamboa Forest "B" site. Eighteen of these catastrophic failures were indicated by either corrosion or swelling of the BA-399 battery.

Occurrences of minor fungal growth were noted at several sites but resulted in no apparent damage to the batteries. Termite infestation was also observed at the exposure sites. Infestation occurred mostly at the Fort Sherman Forest and Coco Solo Open sites and usually resulted in damage to the box in which the battery was stored. On two occasions, termite damage to the battery cardboard case was noted.

•Battery BA-505

Upon retrieval, BA-505 batteries were visually inspected and tested for available voltage and electrical capacity. The minimum performance criteria as specified in MIL-B-18/251 (EL)[11] were used in the determination of battery deterioration from tropic exposure. Statistical analysis, comparing battery failures at the exposure sites with those of the control site, showed that batteries exposed at the Coco Solo Mangrove site exhibited the most severe deterioration with significant performance deterioration occurring after 2 months of exposure. Fort Sherman Open was next in severity with significant deterioration occurring after the 6th month of exposure. There was no significant degradation in battery performance at the remaining sites. A summary of battery performance data is presented in table 9.

Table 9. Number of BA-505 Batteries Failing Performance Criteria as a Function of Exposure Time*

Site	Total Failure Percentage	Exposure Time, weeks 9	18	27	36	45	54
Coco Solo Mangrove	97	4	5	5	5	5	5
Ft Sherman Open	73	0	3	5	5	4	5
Ft Sherman Forest	30	0	0	3	1	2	3
Gamboa Forest "B"	23	1	0	1	0	4***	**
Gamboa Forest "A"	23	0	2	2	1	1	1
Chiva Chiva Open	17	1	0	0	2	2	0
Miraflores Lab	12	1	1	0	1	0	**
Coco Solo Open	7	0	0	0	0	1	1
Ft Gulick Open	7	1	1	0	0	0	0

* Thirty batteries were initially exposed at each site; every 9 weeks thereafter, five batteries from each site were retrieved and tested.

** Data not available.

*** Six batteries were tested at this time.

As with the BA-399 battery, occurrences of corrosion on the battery terminals and/or swelling of the battery were recorded and correlated with battery performance determined in accordance with the MPC. The results are shown in the table below. The numbers in the table are the number of batteries belonging to the tabulated categories.

Minimum Performance Criteria	Corrosion/Swelling Yes	No
Fail	58	6
Pass	8	164

As indicated by the above table, occurrence of corrosion on or swelling of the BA-505 battery is a good predicator of battery performance. Ninety-one percent of the batteries which failed the minimum performance criteria had evidence of corrosion on the battery terminals and/or swelling, while only 12 percent of the batteries which had corrosion and/or swelling were acceptable in accordance with the minimum performance criteria.

Occurrence of fungus growth on the BA-505 battery was noted at the forest exposure sites and at the Fort Sherman Open site. It was most prevalent at the Fort Sherman Forest and Open Sites, but no apparent deterioration in battery performance resulted from the fungus growth.

2.3.3 V-Belts.

Upon retrieval, a sample of the V-belts were subjected to the fatigue test described in paragraph 2.2.3. The performance test parameter measured was the running time before failure of the belts. Prior to the fatigue test, all belts were visually inspected for microbial growth on their inner and outer circumferences and on their sidewalls. The percentage of microbial coverage was recorded and compared to the performance data in an attempt to relate visually observed deterioration to performance degradation. In addition, belt shrinkage occurring during tropic exposure was measured and compared to the performance data to determine its effectiveness as a nondestructive test procedure for predicting belt performance.

Laboratory control performance data were used as baseline data in establishing a minimum performance criterion (MPC) of 10 hours for the minimum acceptable running time of the belts. Analysis using the Chi-square test (alpha = 0.05) and the MPC showed that all exposure sites except Gamboa Forest "B" were significantly different from the laboratory control site. Table 10 presents a summary of the V-belt performance data as a function of exposure time.

The results of the visual inspections for microbial growth on the belts are summarized in tables 11 through 13. Analysis of the microbial growth data indicated that, in general, the percentage of microbial coverage on the belts was not a good predictor of V-belt performance. For example, tables 10 through 13 show that there were relatively low percentages of microbial coverage at the Chiva Chiva Open and Fort Sherman Open sites at times when significant deterioration in belt performance was evident. Percent microbial coverage on the

Table 10. V-Belt Performance as a Function of Exposure Time

Site	9 MPC pass	9 MPC fail	18 MPC pass	18 MPC fail	27 MPC pass	27 MPC fail	36 MPC pass	36 MPC fail	45 MPC pass	45 MPC fail	54 MPC pass	54 MPC fail
Ft Sherman Forest	6	4	2	3	*	*	*	*	*	*	0	9**
Ft Sherman Open	7	3	4	2	4	2	0	6**	1	8**	*	*
Coco Solo Open	5	3	4	4	1	5	*	*	*	*	2	8**
Coco Solo Mangrove	2	8	2	4	0	10**	*	*	*	*	*	*
Ft Gulick Open	2	8	2	4	1	5	*	*	*	*	0	10**
Chiva Chiva Open	6	4	1	5	3	3	0	6**	*	*	2	7**
Gamboa Forest "A"	4	6	2	4	*	*	*	*	0	10**	*	*
Gamboa Forest "B"	4	6	1	5	2	0	4	5	*	*	*	*
Miraflores Lab	1	1	7	6	1	1	*	*	1	0	4	0

Table 11. Average Percent Microbial Coverage on V-Belt Sidewalls as a Function of Exposure Time

Site	9	18	27	36	45	54
Ft Sherman Forest	41	100	100	100	100	100
Ft Sherman Open	8	37	85	75	54	74
Coco Solo Open	1	3	6	4	9	15
Coco Solo Mangrove	47	55	70	33	26	60
Ft Gulick Open	5	13	12	66	28	70
Chiva Chiva Open	1	5	5	4	12	20
Gamboa Forest "A"	25	86	95	93	97	100
Gamboa Forest "B"	56	25	33	23	*	*

Exposure Time (weeks)

* Data not available
** Performance significantly different from that of control lab belts (alpha = 0.05)

Table 12. Average Percent Microbial Coveragae on V-Belt Outer Circumference as a Function of Exposure Time

Site	Exposure Time (weeks) 9	18	27	36	45	54
Ft Sherman Forest	67	64	64	46	51	64
Ft Sherman Open	8	31	58	19	14	33
Coco Solo Open	17	60	52	62	88	98
Coco Solo Mangrove	47	57	56	28	19	45
Ft Gulick Open	23	45	35	50	82	80
Chiva Chiva Open	0	16	19	16	82	74
Gamboa Forest "A"	41	23	88	90	87	70
Gamboa Forest "B"	40	12	43	12	*	*

Table 13. Average Percent Microbial Coverage on V-Belt Inner Circumference as a Function of Exposure Time

Site	Exposure Time (weeks) 9	18	27	36	45	54
Ft. Sherman Forest	5	32	45	36	71	70
Ft Sherman Open	0	6	17	15	9	22
Coco Solo Open	0	0	0	18	2	0
Coco Solo Mangrove	9	36	67	25	19	49
Ft Gulick Open	0	2	4	32	7	7
Chiva Chiva Open	0	1	0	0	3	2
Gamboa Forest "A"	2	8	21	54	52	60
Gamboa Forest "B"	25	16	21	31	*	*

* Data not available

sidewalls and on the outer and inner circumferences of the belts exposed for 36 weeks at the Chiva Chiva Open site was 4, 16 and 0 percent, respectively, while all belts tested had a running time before failure of less than 2.5 hours. Percent microbial coverage on the inner and outer circumferences of the belts exposed for 36 weeks at the Fort Sherman Open site was 19 and 15 percent, respectively, while all belts tested had a running time before failure of less than 3.8 hours.

Analysis of the belt shrinkage data showed that all belts shrank to some degree during tropic exposure, with the amount of shrinkage being effectively independent of the subsequent fatigue test results. As a percentage of initial length, V-belts which passed the minimum performance criterion had a mean shrinkage of 2.4 percent with a standard deviation of 1.0 percent, while belts which failed the minimum performance criterion had a mean shrinkage of 2.6 percent with a standard deviation of 1.0 percent.

2.3.4 Roller Bearings.

Bearing serviceability was judged at each retrieval in accordance with the criteria described in paragraph 2.2.4. A summary of the results of the visual inspections of the bearings is presented below.

	Number of Bearings		
Site	Serviceable Without Qualification	Serviceable After Cleaning	Unserviceable
Coco Solo Mangrove	0	0	60
Gamboa Forest "B"	0	0	50
Gamboa Forest "A"	12	7	37
Ft Sherman Forest	11	25	24
Ft Sherman Open	26	6	28
Coco Solo Open	12	8	30
Ft Gulick Open	34	9	3
Chiva Chiva Open	29	1	0
Miraflores Lab	52	8	0

The bearing serviceablility results were analyzed using the Chi-square test (alpha = 0.05). The most severe sites were the Coco Solo Mangrove and Gamboa Forest "B" sites where there were no acceptable bearings at any inspection. The Fort Sherman Forest and Gamboa Forest "A" sites were next in severity with significant corrosion evident after 4 months of exposure. They were followed by the Coco Solo Open and Fort Sherman Open sites where significant corrosion of the bearings occurred after the 6th month of exposure,

and by the Fort Gulick Open site where significant corrosion was evident after the 10th month of exposure. After 12 months of exposure, the serviceability of bearings at the Chiva Chiva Open site was not significantly different from that at the control site.

2.3.5 POL Products (Gasoline and Diesel).

Upon retrieval gasoline and diesel samples were inspected visually for any water layer or emulsion. In no case was any water separation or emulsion observed. The contents were then shaken with indicating desiccant to determine the presence of trace amounts of water. As before, none was found. Compositional analysis performed by gas chromatography revealed the absence of any new products, indicating that no significant oxidation or microbial attack occurred during the exposure. No significant changes occurred in the composition of the exposed diesel and gasoline except for a partial loss of the lighter, more volatile components. The loss of the lighter components is attributable to the high vapor pressure of the lighter components at tropic ambient temperatures. At the temperatures encountered during exposure, significant pressure would build up inside the fuel container causing leakage through the cap gasket. However, in the case of containers perforated by corrosion, the process of volatilization and evaporation of the lighter fuel components was substantially accelerated. For example, losses of up to 49 percent of 2-methyl butane content were measured in the gasoline of perforated cans while the gasoline in unperforated cans had losses of approximately 10 percent .

The most severe corrosion of fuel containers occurred at sites where the pallet and tarpaulin mode of exposure was used. These sites accounted for all occurrences of perforated cans. Forty-eight percent of the gasoline cans and 24 percent of the diesel fuel cans exposed at these sites had perforations. Occurrences of container failure became significant after 6 months of exposure for the gasoline cans, while the failures of the diesel fuel cans appeared to be randomly distributed. The tables below present the number of perforated fuel cans as a function of exposure time.

Number of Perforated Gas Cans*
as a Function of Exposure Time

Site	Exposure Time (weeks) 9	18	27	36	45	54
Ft Sherman Open	0	2	4	4	4	4
Coco Solo Mangrove	0	1	4	4	5	5
Gamboa Forest "B"	0	0	1	0	**	**

* Thirty cans were initially exposed at aeach site; every 9 weeks thereafter, the cans from each site were retrieved and examined.
** Data not available

Number of Perforated Diesel Cans*
as a Function of Exposure Time

Site	Exposure Time (weeks) 9	18	27	36	45	54
Ft Sherman Open	1	2	0	2	0	0
Coco Solo Mangrove	0	2	2	0	1	0
Gamboa Forest "B"	4	2	3	0	**	**

* Thirty cans were initially exposed at each site; every 9 weeks thereafter, five cans from each site were retrieved and examined.
** Data not available.

Most of the fuel cans exposed under tarpaulins exhibited a "standing water" corrosion pattern on the top surface, where the water was contained by the lip around the can. In the other exposure modes, corrosion was much less severe, evidenced by a speckled appearance around welds initially and then spreading to other areas.

2.3.6 Windshield Wiper Motor.

Retrieval and testing of the motors was in accordance with the retrieval scheme described in paragraph 2.2.6. A plot of the performance parameter, partial vacuum (mm Hg), measured at the Miraflores Laboratory control site is shown in figure 10. Figure 11 presents a consolidated plot of the performance parameter as a function of time for all field exposure sites.

As indicated by the figures, the performance parameter varied similarly for all motors, both those exposed to the humid tropical environment and those at the control site. The vacuum requirement for all motors was approximately 250 mm Hg at the commencement of the exposure period and decreased to approximately 190 mm Hg over a period of 280 days. It remained essentially constant at 190 mm Hg for the remainder of the exposure period.

Statistical analysis was conducted on the performance data collected after 280 days of exposure. The method of least-squares was used to determine equations of the best-fit straight lines for the data from each site. The slopes of the lines obtained for each field exposure site were compared to that obtained for the control site using an F-ratio test (alpha = 0.05). No statistically significant degradation in motor performance was occurring because of humid tropic exposure.

Corrosion of the shaft bushing (connection point of the wiper arm) was found to be present on significant quantities of motors only at the Coco Solo Mangrove site, after 6 months of exposure. However, it never caused the failure of any motor even after an additional 1 year of exposure.

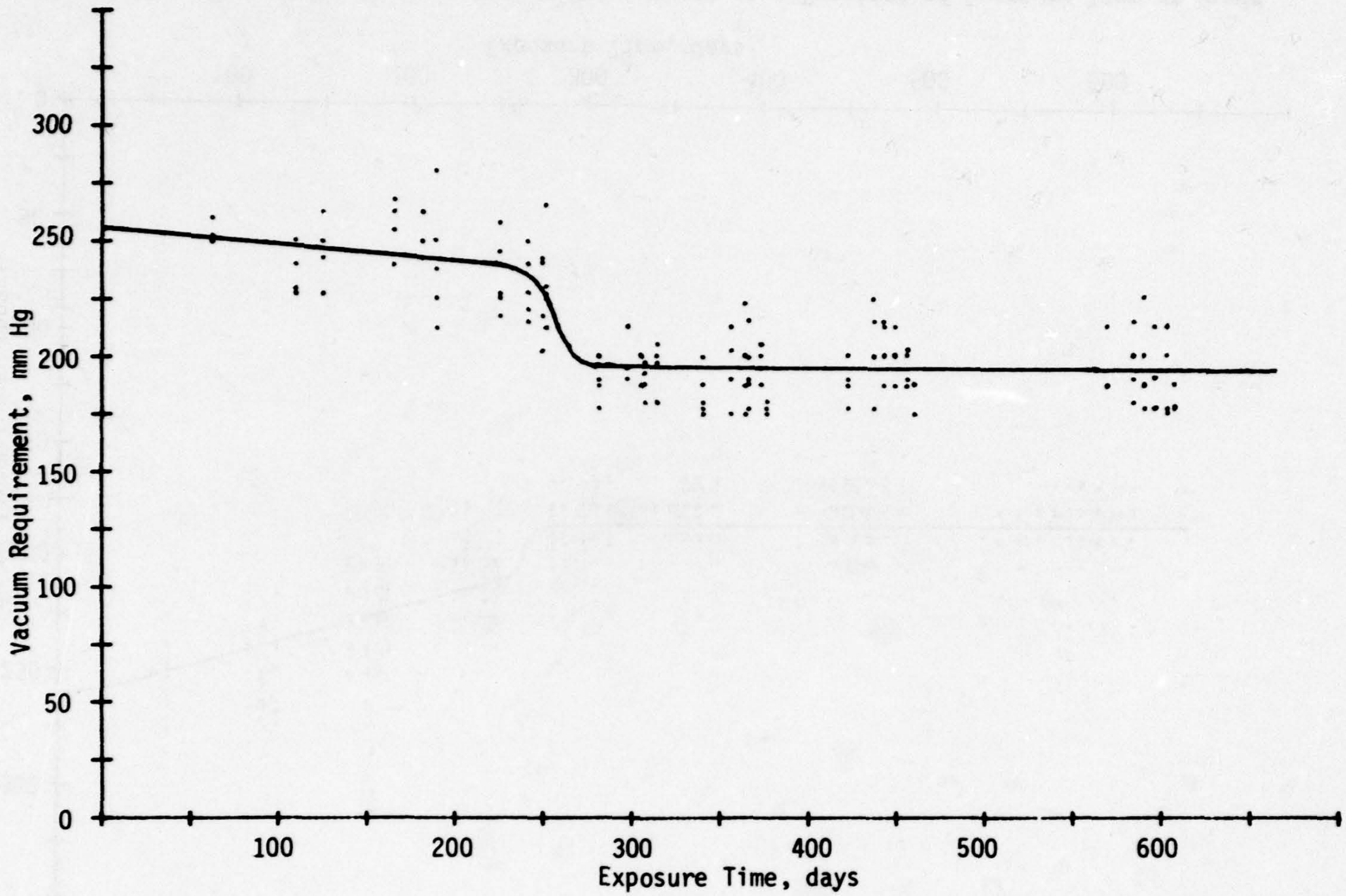

Figure 10. Wiper Motor Minimum Vacuum Requirement as a Function of Exposure Time at the Laboratory Control Site.

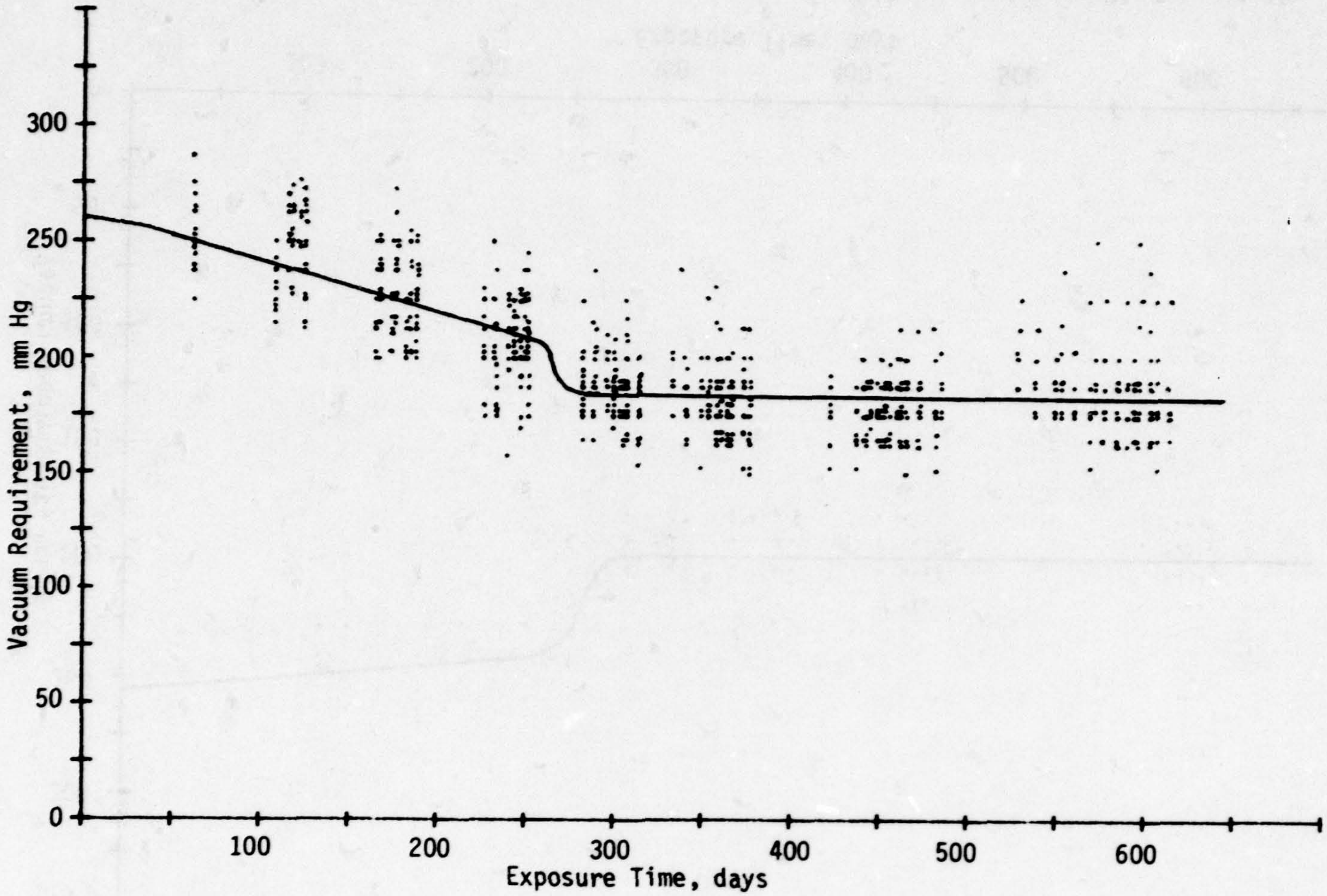

Figure 11. Wiper Motor Minimum Vacuum Requirement as a Function of Exposure Time at Humid Tropic Field Sites.

The motors at both pallet and tarpaulin-forest sites exhibited severe blistering and peeling of paint. Blistering of paint was observed on all motors after 2 months exposure at the Coco Solo Mangrove site, while 90 percent of the motors at the Gamboa Forest "B" site exhibited blistering after 4 months of exposure. Minor blistering was also observed at the shed-forest and pallet and tarpaulin-open sites after 10 months of exposure and at the shed-open sites after 16 months of exposure.

Significant occurrences of fungal growth on motors were found at the Fort Sherman Forest and Fort Sherman Open sites which were similar in severity. Substantial fungal growth on the motors also occurred at the Gamboa Forest "A" site but was confined to the later half of the 19-month exposure period.

2.3.7 Windshield Wiper Blades.

Wiper blades were performance tested with a criterion of wiping a windshield completely clear of a suspension of clay soil in water in 20 strokes or fewer. Occurrence of failure to meet this criterion (table 14) was analyzed using the Chi-square test (alpha 0.05). By this criterion, the forest exposure sites were the most severe sites having a significant number of blade failures which was statistically different from that of the control site. The occurrence of test failures of the blades (18 out of 20) exposed at the forest sites was significant after 9 weeks of exposure.

Table 14. Number of Blades Failing Performance Criterion as a Function of Exposure Time*

Site	Exposure Time (weeks) 9	18	27	36	45	54
Coco Solo Mangrove	5	5	5	5	5	5
Gamboa Forest "B"	4	5	4	4	**	**
Ft Sherman Forest	5	5	5	3	3	4
Gamboa Forest "A"	4	3	5	3	5	4
Ft Sherman Open	3	3	5	3	4	5
Ft Gulick Open	3	2	4	4	4	5
Chiva Chiva Open	3	3	4	4	3	4
Coco Solo Open	1	0	3	4	4	4
Miraflores Lab	1	2	4	2	3***	**

* Thirty blades were initially exposed at each site; every 9 weeks thereafter, five blades from each site were retrieved and performance tested.

** Data not available.

*** Only four blades were performance tested.

A summary of the visual examinations of the blades is presented in table 15. The visually observed deteriorative effects on the blades included (1)corrosion at the wiper arm connection points (2)corrosion at the ends of the blades and along its backbone and blistering and peeling of paint at other locations, and (3) fungal growth on painted surfaces and on the blade rubber. All proved to be poor predictors of blade performance as evidenced by the lack of corrosion on the connection point at the Fort Sherman Forest and Gamboa Forest "A" sites, the relatively low occurrence of blistering of paint and general corrosion at the Gamboa Forest "A" site, and the lack of fungal growth on blades at the Coco Solo Mangrove and Fort Sherman Forest sites.

Table 15. Percentage of Blades Exhibiting External Deterioration

Site	Corrosion on the Connection Point	Blistering of Paint and General Corrosion	Fungal Growth
Coco Solo Mangrove	100	100	0
Gamboa Forest "B"	45	100	55
Ft Sherman Forest	0	77	0
Gamboa Forest "A"	0	43	90
Ft Sherman Open	40	93	17
Ft Gulick Open	0	50	47
Chiva Chiva Open	0	7	30
Coco Solo Open	0	27	0
Miraflores Lab	0	0	0

2.3.8 Interval Timers.

The timers were tested for actual running time for a 30-minute setting. The method of least-squares was used to determine equations of the best-fit straight lines for the performance data from each site. F-ratio tests (alpha = 0.05) of the slopes of these lines showed that the running times of the timers exposed at the field sites were increasing significantly as a function of exposure time. Analysis also showed that the slopes of the lines obtained for sites with the same exposure mode, e.g., Shed-Forest, were not significantly different. Therefore, the sites were grouped by exposure mode and a common slope or degradation rate was computed for each exposure mode. The degradation rates are listed in table 16 and plots of the performance parameter as a function of exposure time are presented in figures 12 through 16. The 95-percent prediction intervals about the regression line are represented by dashed curves.

The most severe mode was the pallet and tarpaulin-forest exposure mode. The actual running time of the timers exposed in this mode was increasing at the rate of 0.30 minute per month. This result tracked well with the occurrences of timer failure. One hundred percent and

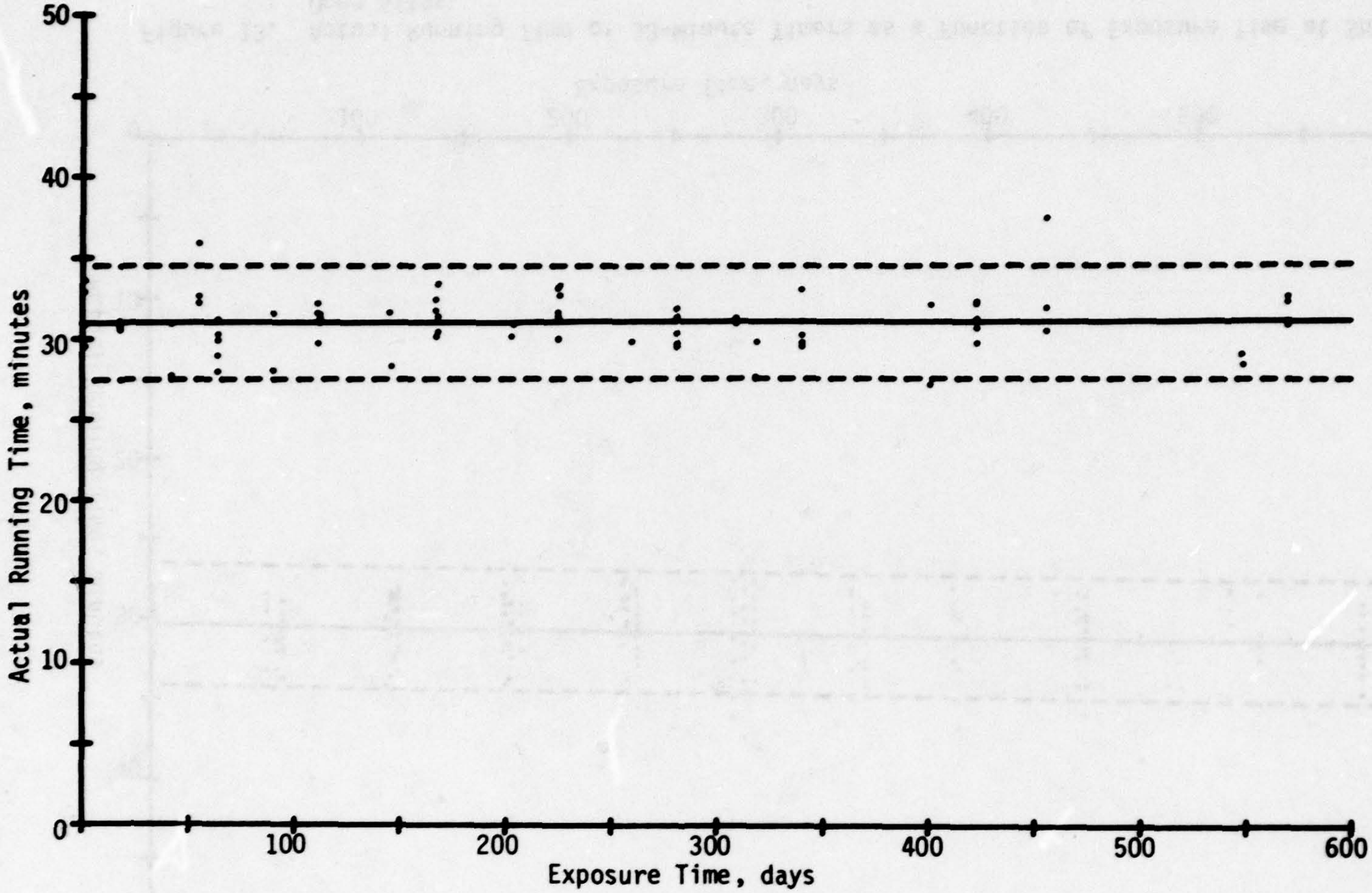

Figure 12. Actual Running Time of 30-Minute Timers as a Function of Exposure Time at the Laboratory Control Site.

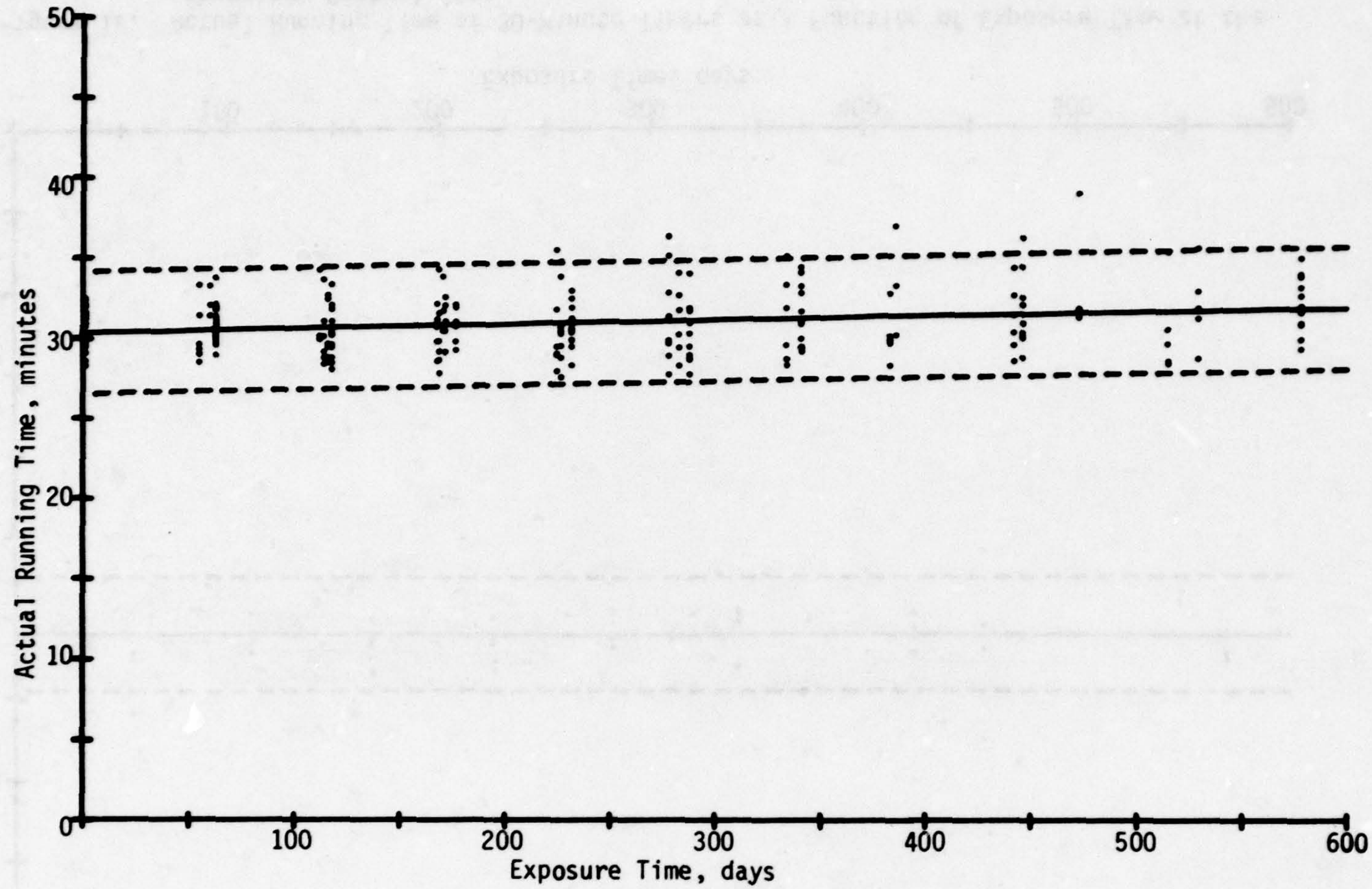

Figure 13. Actual Running Time of 30-Minute Timers as a Function of Exposure Time at Shed-Open Sites.

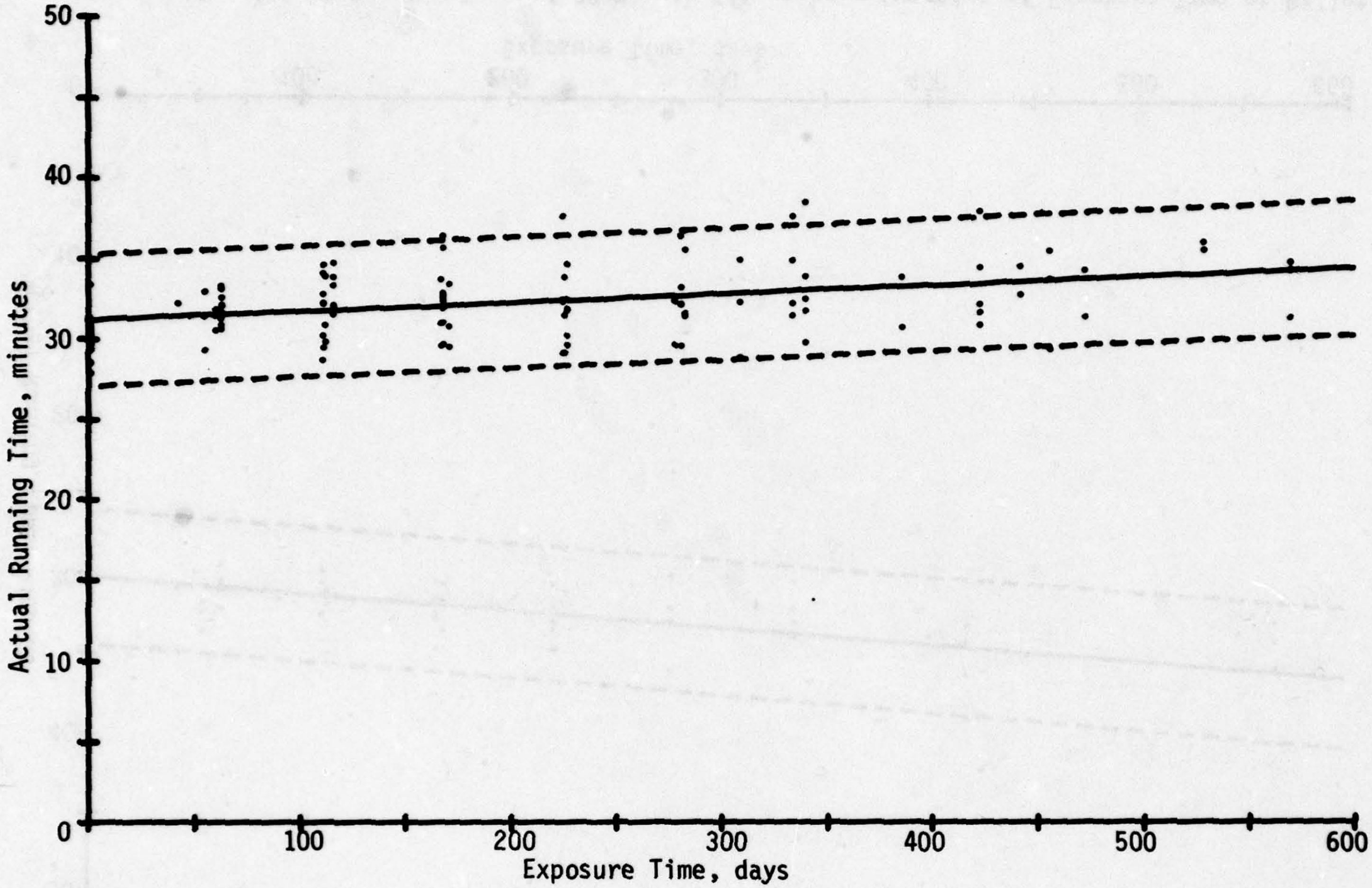

Figure 14. Actual Running Time of 30-Minute Timers as a Function of Exposure Time at Shed-Forest Sites.

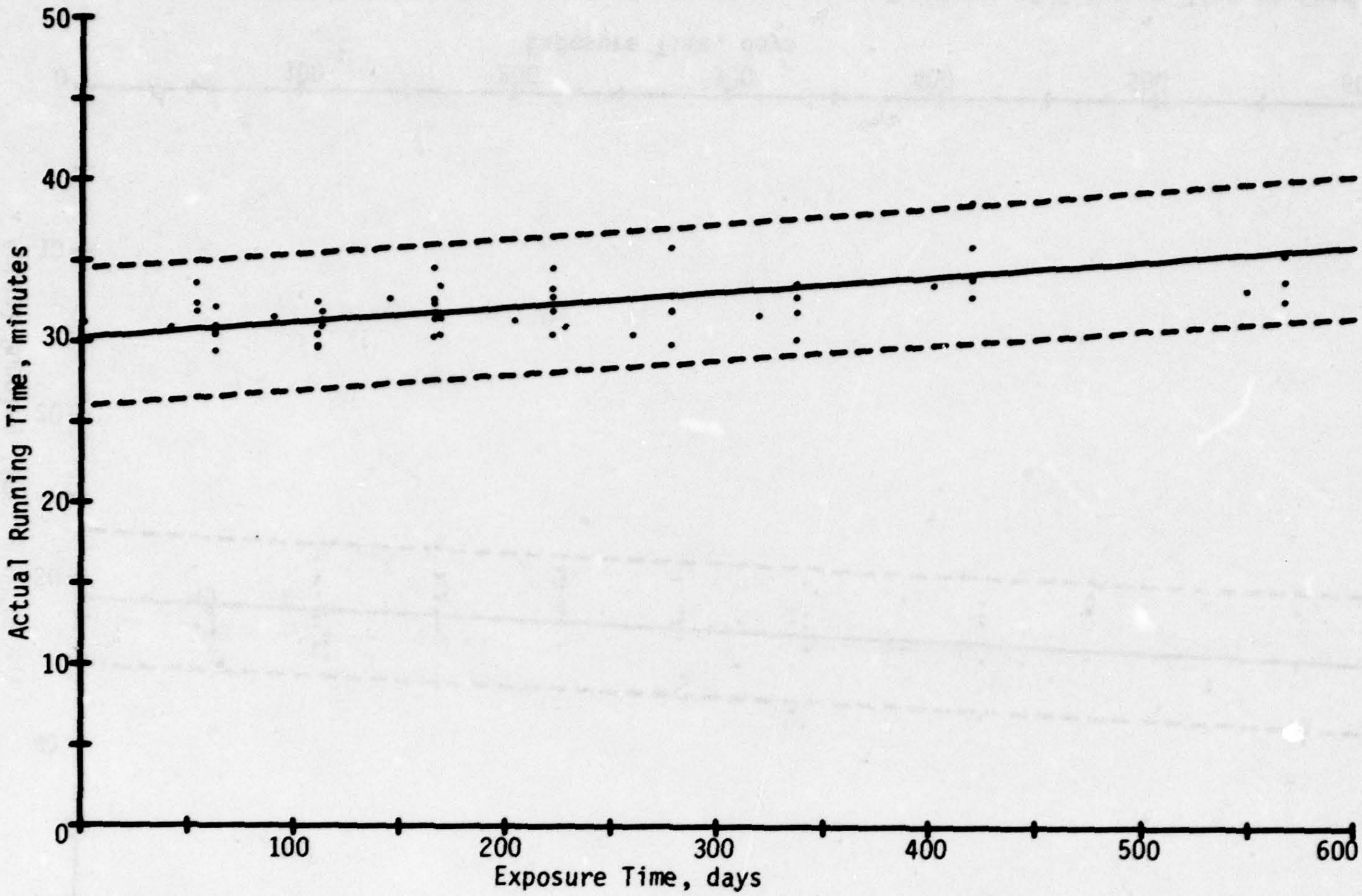

Figure 15. Actual Running Time of 30-Minute Timers as a Function of Exposure Time at Pallet and Tarpaulin - Open Sites.

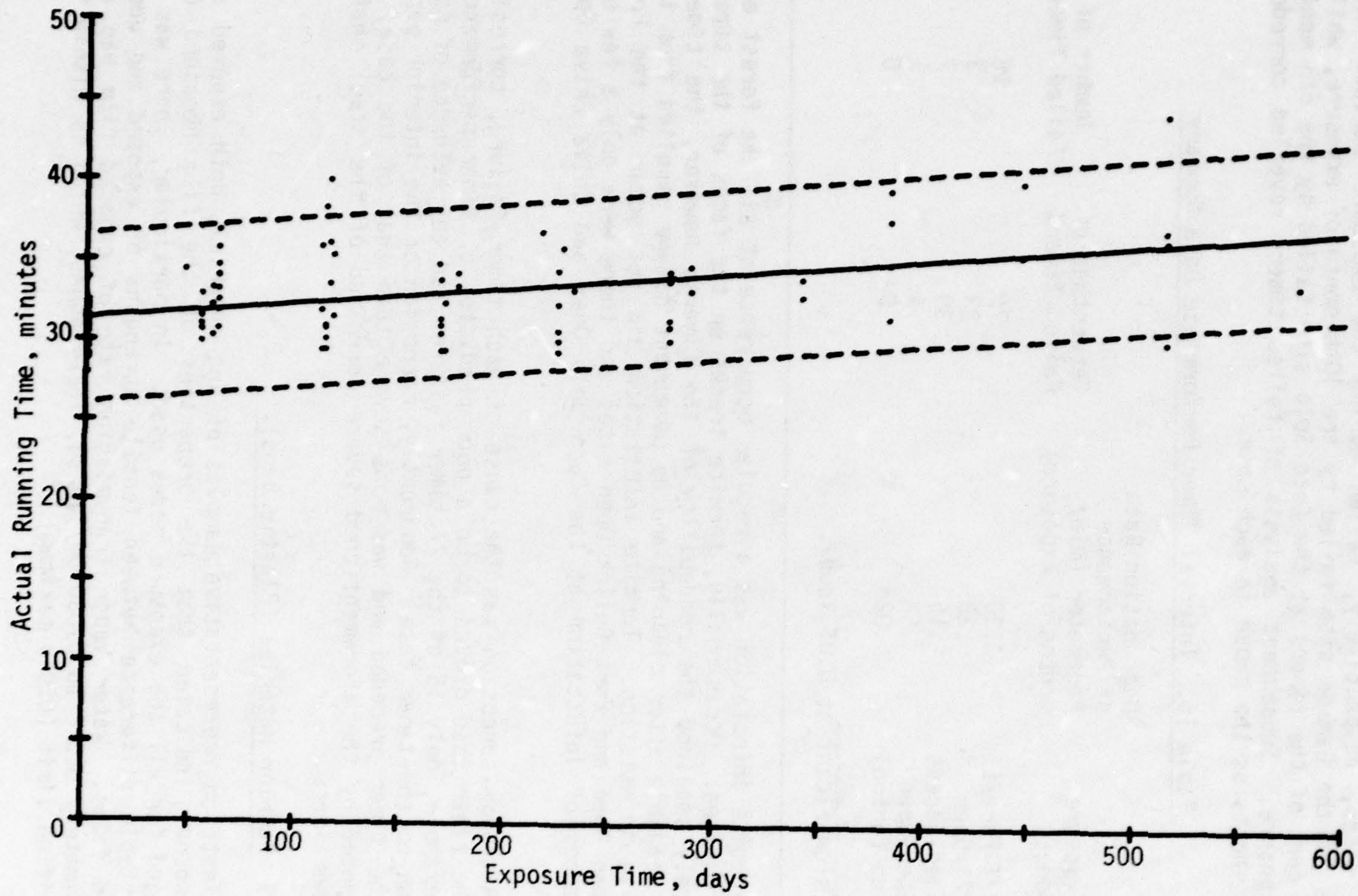

Figure 16. Actual Running Time of 30-Minute Timers as a Function of Exposure Time at Pallet and Tarpaulin - Forest Sites.

58 percent of the timers at the Gamboa Forest "B" and Coco Solo Mangrove sites, respectively, failed during the exposure period. All timers at the Gamboa site failed by the 10th month of exposure, while 42 percent of the timers at the Coco Solo site failed by the 6th month of exposure. Subsequent analysis of failed timers revealed corroded steel shafts as the cause in each case.

Table 16. Interval Timer Performance Data Summary

Exposure Mode	Degradation Rate of Performance Parameter (min/ months of exposure)	Percentage of Failed Timers	Number of Failed Timers
P/T-Forest	.30	76	16
P/T-Open	.20	33	3
Shed-Forest	.16	39	7
Shed-Open	.08	4	1
Lab Control	.02*	0	0

*Not significant at 0.05 level.

Termite infestation was a regular occurrence at all the forest exposure sites. Occasionally, termite tracks on the faces of the timers severely impaired the readability of the timers; however, the timers were readable after cleaning and no permanent damage resulted from the termite infestation. Termite infestation did not occur at the Fort Sherman Open and Fort Gulick Open sites and there were only a few occurrences of infestation at the Coco Solo Open and Chiva Chiva Open sites.

Although corrosion was the cause of each timer failure, corrosion of the timer case proved to be a poor predictor of timer performance. For example, only 15 of the 27 timer failures had any evidence of corrosion on the timer case. Apparently, corrosion of the interior parts of the timer preceded and was more severe than that of the case, as evidenced by the aforementioned severe corrosion of the steel shafts in the timers.

2.3.9 Barrier Materiel (Plastic Bags).

Tests on representative samples of bag materiel, both exposed and unexposed, indicated that the properties of the film remained unchanged for all the exposure modes used. In particular, there was no detectable difference between tensile strengths of exposed and unexposed films. Water vapor transmission rate of exposed film was approximately 0.026 to 0.030 gm/100 sq. in/24 hours, which is within the specified limit (0.045 maximum).

The amount of moisture permeating into the 100 grams of desiccant which was placed inside the plastic bags was measured by weighing the bags before and after exposure. Analysis of the data by exposure mode showed that there was no significant difference between the field exposure modes. The average weight gain after 54 weeks of exposure is presented in the table below for each exposure site.

Site	Exposure Mode	Average Weight Gain (g)
Coco Solo Open	Shed	21.5
Coco Solo Mangrove	P/T	20.8
Gamboa Forest "B"	P/T	19.8
Fort Gulick Open	Shed	19.5
Fort Sherman Forest	Shed	19.3
Fort Sherman Open	P/T	18.9
Gamboa Forest "A"	Shed	18.2
Chiva Chiva Open	Shed	16.8
Miraflores Lab	Air-conditioned	8.5

The occurrence of microbial growth on the plastic bags was most frequent at the Fort Sherman Open Site (27 of 30 bags), while the occurrence of water spots and mud was more prevalent at the two pallet and tarpaulin-forest exposure sites (30 of 30). Both proved to be poor indicators of bag quality and of the quantity of permeating moisture.

2.3.10 Practice Rockets, 3.5-Inch.

At the end of the 54th week of exposure to the humid tropics, the practice rockets (nine rockets per site) were disassembled and nine areas or parts of each rocket fuze were examined for corrosion. Table 17 summarizes the results of the visual examinations. The table presents the number of fuze parts which exhibited corrosion, classified in accordance with the criteria described in paragraph 2.2.10, for each exposure site.

The most severe corrosion of the rocket fuzes occurred at the forest exposure sites. Moderate to severe corrosion was found on 42, 38, 37, and 36 percent of the fuze parts at the Gamboa Forest "B," Coco Solo Mangrove, Fort Sherman Forest, and Gamboa Forest "A" sites, respectively. There were two nonfunctional fuzes at the Gamboa Forest "B" site. The two fuzes had nonfunctional, non-return springs which had split into two parts because of corrosion.

Corrosion, to a lesser degree, was found on the parts of rocket fuzes exposed at the open exposure sites. Minor to moderate corrosion was evident on 44, 42, and 36 percent of the fuze parts at the Fort Sherman Open, Coco Solo Open, and Fort Gulick Open sites, respectively. Corrosion was least apparant at the Chiva Chiva Open and Miraflores Laboratory sites where only minor corrosion occurred on 22 percent of the fuze parts.

Table 17. Number of Rocket Fuze Parts Exhibiting Corrosion

Site	Class	Exterior Fuze Surface	Safety Pin	Safety Pin Spring	Setback Plunger	Plunger Spring	Outside Surface of Plug	Inside Surface of Plug	Non-Return Pin	Non-Return Pin Spring	Total
		Rocket Fuze Parts									
Gamboa Forest "B"	Minor	5	3	3	1	2	4	2	1	2	23
	Moderate	0	4	2	3	4	4	2	1	0	20
	Severe	0	1	0	3	1	0	3	3	1	12
	Failure	0	0	0	0	0	0	0	0	2	2
Coco Solo Mangrove	Minor	0	1	2	2	5	1	4	4	3	22
	Moderate	2	3	2	5	2	6	3	0	1	24
	Severe	1	2	0	1	0	1	1	1	0	7
Gamboa Forest "A"	Minor	0	2	4	2	4	2	5	3	5	27
	Moderate	0	3	5	3	4	3	2	0	0	20
	Severe	0	3	0	3	0	2	0	1	0	9
Ft Sherman Forest	Minor	0	4	2	7	3	2	5	1	2	26
	Moderate	0	3	3	1	5	5	2	2	2	23
	Severe	0	1	0	1	1	0	2	1	1	7
Ft Sherman Open	Minor	1	5	2	5	4	2	6	0	1	26
	Moderate	0	1	3	1	2	0	1	0	1	9
	Severe	0	0	0	0	0	0	0	1	0	1
Ft Gulick Open	Minor	0	4	2	3	3	1	4	2	3	22
	Moderate	0	1	0	1	1	1	0	1	1	6
	Severe	0	0	0	1	0	0	0	0	0	1
Coco Solo Open	Minor	0	4	3	4	5	1	4	2	0	23
	Moderate	0	2	0	2	1	0	2	1	3	11
Chiva Chiva Open	Minor	0	4	0	3	4	0	4	1	3	19
	Moderate	0	0	0	0	0	0	0	0	0	0
Miraflores Laboratory	Minor	0	1	3	2	5	1	2	1	2	17
	Moderate	0	0	0	0	0	0	0	0	1	1

The exterior surface of the rocket fuze represented the most corrosion-resistant part of the fuze. Table 17 shows that only 9 of the 72 rocket fuzes exposed to the humid tropics had evidence of any corrosion on their exterior surfaces, while the occurrences of corrosion on the interior parts of the fuzes were more numerous and of greater severity. Table 18 shows more clearly the association between exterior and interior corrosion of the rocket fuzes. The table lists for each exposure site the number of fuzes which exhibited extensive internal corrosion, i.e., occurrences of severe corrosion on one or more internal parts or of moderate corrosion on three or more internal parts. The last two columns of table 18 list the number of fuzes with exterior surface corrosion that also had (1) extensive internal corrosion or (2) only minor internal corrosion. As indicated by the table, only 6 of the 31 fuzes with extensive internal corrosion had any evidence of visible corrosion on their exterior surfaces. This not only indicates the higher corrosion-resistant nature of this surface but also the requirement for a thorough inspection of similar materiel items undergoing tropic development and surveillance testing to determine the full extent of tropic deterioration.

Periodically during the exposure period, the rockets were examined radiographically in the field. The radiographs of the rockets were clear and readable, and all of the parts in the fuze were clearly visible, except the non-return spring which was beyond the resolution capability of the system used. Thus, the two fuzes in which the non-return spring had failed because of corrosion were not identified as being nonfunctional by radiography. Some corrosive effects were indicated by radiographic examination, particularly the reduction of clearance between the fuze body and the setback plunger caused by corrosion between the two parts. Severe corrosion of the setback plunger springs was also indentified by the radiographs; however, the majority of parts exhibiting moderate to severe corrosion were not positively identified by radiography.

Table 18. Association Between Interior and Exterior Corrosion of Rocket Fuzes

Site	No. of Fuzes with Extensive Interior Corrosion	No. of Fuzes with Exterior Corrosion: Associated with Extensive Internal Corrosion	No. of Fuzes with Exterior Corrosion: Associated with Minor Internal Corrosion
Gamboa Forest "A"	7	0	0
Gamboa Forest "B"	6	3 minor	2 minor
Coco Solo Mangrove	6	2 moderate, 1 severe	0
Ft Sherman Forest	6	0	0
Coco Solo Open	3	0	0
Ft Sherman Open	2	0	1 minor
Ft Gulick Open	1	0	0
Chiva Chiva Open	0	0	0
Miraflores Lab	0	0	0
Total	31	6	3

SECTION 3. APPENDIXES

APPENDIX A. TEST DIRECTIVE AND METHODOLOGY INVESTIGATION PROPOSAL

(COPY)

DEPARTMENT OF THE ARMY
HEADQUARTERS, U. S. ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MARYLAND 21005

AMSTE-ME 28 June 1974

SUBJECT: Test Directive, Exposure/Performance Tests of Selected Materiel Items, TRMS No. 9-CO-009-000-016

Commander
US Army Tropic Test Center
ATTN: STETC-PD-M
Drawer 942
Fort Clayton, CZ

1. References:

a. TECOM Regulation 70-12, dated 1 June 1973.

b. Letter, AMSTE-ME, dated 13 March 1974, subject as above.

2. This letter and attached STE Form 1189 (Incl 1) constitute a test directive for continuation of the subject investigation under the TECOM Methodology Improvement Program 1U7865702D625.

3. The Methodology Investigation Proposal at Inclosure 2 and the additional guidance provided at Inclosure 3 are the bases for headquarters approval of the subject investigation. Any deviation from the approved scope, procedures, and authorized cost will require approval from this headquarters prior to execution.

4. Special Instruction:

a. All reporting will be in consonance with paragraph 9 of reference 1a. The final report, when applicable, will be submitted to this headquarters, ATTN: AMSTE-ME, in consonance with Test Event 52, STE Form 1189.

AMSTE-ME
SUBJECT: Test Directive, Exposure/Performance Tests of Selected Materiel Items, TRMS No. 9-CO-009-000-016

b. Recommendations of new TOPs or revision to existing TOPs will be included as part of the recommendation section of the final report. Final decision on the scope of the TOP effort will be made by this headquarters as part of the report approval process.

c. The utilization of the funds provided to support the final investigation is governed by the rules of incremental funding.

d. The addressee will determine whether any classified information is involved and will assure that proper security measures are taken when appropriate.

e. The point of contact at this headquarters is Mr. Albert Crowell, Autovon 870-3293.

FOR THE COMMANDER:

/s/Sidney Wise
/t/SIDNEY WISE
Dir, Methodology Improvement

3 Incl
as

(END COPY)

(COPY)

July 1973

1. TITLE. Exposure/Peformance Tests of Selected Materiel Items

2. INSTALLATION. U. S. Army Tropic Test Center
P. O. Drawer 942
Fort Clayton, Canal Zone

3. PRINCIPAL INVESTIGATION. G. F. Downs
Analysis Branch
STETC-OO-A
Autovon 313 287-5462

4. BACKGROUND. This project has been active since October 1972 and will end 31 December 1974. The present MIP covers only the first half of FY75. Although the ultimate goal of tropical testing is to insure the satisfactory performance of materiel, very little work has been done relating materials deterioration to the performance of materiel items. In a previous project, "Determination of Optimum Tropic Storage and Exposure Sites", 9-CO-009-000-006, sixteen sites were characterized using the deterioration of six materials to give a severity index for each site. It was found that no single index would characterize a site for all materials because different combinations of environmental effects are active in the deterioration of each material.

To better understand the relationships between exposure, materials deterioration and performance of materiel items, commonly used test items have been selected and will be exposed and tested for performance. These items were selected on the basis of being particularly susceptible to tropic deterioration. Other criteria include accuracy of performance testing.

5. STATEMENT OF THE PROBLEM. Tropical deterioration investigation must be extended from materials to materiel. The effects of tropical exposure on performance, as well as deterioration rate, must be identified. Simultaneously, specific materiel deterioration identifies need to be developed that will predict equipment degradation more accurately than commonly measured environmental factors. In a previous investigation it was shown that: (a) each material used was deteriorated by a distinct combination of environmental factors, and (b) the relative effect of each factor varied considerable from one material to another. In most cases, although deterioration patterns and rates varied widely, the commonly measured environmental parameters were almost uniform.

6. GOALS.

a. To learn how and when to apply nondestructive test instrumentation and techniques to intact test items during static tropic surveillance tests.

b. To learn how and when to measure performance of test items on static tropic exposure and to relate performance measures to corrosion and other visible evidence of degradation.

c. To establish statistical variation in the performance of samples of materiel items prior to static tropic exposure.

7. DESCRIPTION OF INVESTIGATION.

a. The U. S. Army Tropic Test Center will develop performance measures for selected materiel items under tropical exposure. Commonly used test materiel items are being exposed and performance tested. Items believed to be particularly susceptible to tropical deterioration have been selected. Environmental factors, to include condensation/evaporation cycles, atmospheric chemistry, and vegetation influences are being compared with deteriorative effects on materiel end items exposed at sites that previously have shown different deterioration patterns but similar meteorological conditions.

b. The U. S. Army Tropic Test Center will:

(1) Expose relatively simple end items in storage sheds located at sites that showed different deterioration patterns but similar meteorological conditions in a previous investigation. These end items include windshield wiper blades and motors, automotive wheel bearings, automotive fan belts, timers, POL, small batteries, barrier materials, tactical radios, and 3.5 inch rocket cases.

(2) Determine the effects of exposure on items performance by removing items at intervals for examination and testing.

(3) Determine deteriorative effects by using destructive and nondestructive tests as follows:

(a) V-Belts (FSN 3030-832-5671)

Tensile test (one test per item, 5 items at each retrieval per site) tensile strength and elongation will be recorded. Items will be weighed and measured for length before tensile testing. Weight change and length change will be recorded. Representative samples will be service tested to destruction under a standard load.

Exposure/Performance Tests of Selected Materiel Items - Continued

(b) Wiper Motors (FSN 2540-678-1340)

Will be examined for external corrosion, particularly where arm attaches. Will be tested for operation under typical vacuum. Will be tested for speed under standard load (weight on horizontal arm). Will be inspected for internal corrosion by X-ray and/or ultrasonic means.

(c) Wiper Blades (FSN 2540-050-0813)

Will be examined for corrosion at attachment to arm and other locations causing structural weakness. Will be examined for cracking of rubber. Durometer testing of rubber will be attempted but may be abandoned if no significant results were obtained. If rubber is not cracked, blades will be service tested on a simulated windshield. Number of strokes required to wipe clean and streak-free will be counted, using homogenized muddy water (50cc) of a standardized composition and standardized speed and pressure.

(d) Batteries (BA-30, FSN 6135-210-1020) (BA 399/u, FSN 6135-926-0825) (BA505/u, FSN 6135-926-0844)

Will be measured for welling, examined for corrosion, tested for contact resistance and electrical energy content by completely discharging. All 3 types will be tested in the same way.

(e) Timers (FSN 6645-663-8169)

Will be examined for corrosion and readability of face. Will be tested for contact resistance. Will be tested for accurate timing by operating an electric clock or timer through timed circuit. Selected samples will be examined by X-ray for internal effects.

(f) Barrier Materials (Plastic Film) (FSN 8135-068-9466)

Will be exposed as packages of dessicant, approximately 12" square, heat sealed shut. Packages will be weighed upon retrieval to determine water uptake, a measure of packaging serviceability. Film will be tested for tensile strength and elongation and also for water vapor transmission to determine if permeability has changed during the exposure. Samples will be sealed and seal strength will be tested. Three tensile tests and three seal strength tests on each of five retrieved samples per site will be made.

(g) POL Products (Gasoline and Diesel Fuel)

Will be exposed in one gallon tin plate cans and retrieved in groups of five cans of each. Each can will be tested in the following ways:

Examination for leakage, internal corrosion, internal contamination by water, gum formation and microbial growth. Products will be analyzed for chemical changes and additive levels by gas chromatography.

(h) Automotive Roller Bearings:

Each package contains two bearings, a nut, a washer and a cotter pin wrapped in VPI paper. Five packages will be retrieved from each site . All parts will be examined microscopically and macroscopically for corrosion. Representative samples will be service tested to destruction.

(i) Tactical Radios: Transmitter PRT 4A (FSN 5820-133-8980)
Received PRR-9 (FSN 5820-069-8931)

Five of each will be retrieved from storage at each site. All items will be tested for operation and visually examined. Power required for operation will be tested. Transmitters will be tested for operational efficiency (RF output/DC input). Selected samples will be examined for internal change by X-ray.

(j) 3.5-inch Rocket cases (FSN 1340-028-0091)

Will be X-rayed for internal changes. If deemed necessary, containers will be opened for more detailed examination.

(4) Measure the following environmental modifiers continuously at exposure sites.

(a) The quality and quantity of particulate matter in the air around the samples.

(b) The quantity of chlorides, sulfur and nitrogen compounds and other chemical characteristics of the air around the samples.

(5) Determine the surface wetness of the exposed samples. Means to measure this effect are being studied under an instrumentation project.

(6) Develop a computerized prediction model of deteriorative effects of modifiers of climatic influences. It is hypothesized that these modifiers may exert a greater effect on deterioration rates and patterns than minor differences in meteorological conditions in tropical climates.

8. JUSTIFICATION:

a. Association with Mission. TECOM is responsible for tropic surveillance tests of Army materiel items. TTC surveillance consists of 15% of the testing workload. At the present time a total of 5640 items of materiel and 26,000 pounds of explosives and chemicals are on exposure.

b. Present capability, limitations, improvement and impact of test if not approved.

(1) Performance/Failure Predictors

(a) Present capability.

At the present time 5640 test items of materiel and 26,000 pounds of bulk explosives and chemicals are being exposed at TTC. Most of the exposure sites have been calibrated with respect to deterioration severity toward individual materials. No work has been done to relate the deterioration of materials to the performance of end items however. Current performance measures involve one or at most several items of a kind, limiting the statistical validity of the test, and are usually based on subjective judgement of qualitative factors. Quantitative results are seldom obtained.

(b) Limitations.

(i) There are at present no precise guidelines upon which to base time-to-failure predictions.

(ii) There are at present no adequate methods of performance measurement for most materiel items.

(c) Improvement:

(i) The investigation will lead to new procedures to improve prediction of materiel failures caused by the environment.

(ii) The investigation will develop accurate methods of measuring performance of materiel items.

(iii) The investigation will result in new procedures to aid determination of maximum and minimum exposure test times.

(d) Impact:

(i) Items will continue to be exposed and reported upon without adequate performance evaluation.

(ii) Time-to-failure predictions will continue to be made on the basis of subjective judgements without either scientific or statistical substantiation.

(2) Environmental Modifiers:

(a) Present capability:

Much has been learned in previous studies about the influence of vegetation, season and shade on the deterioration of materials. Little attention has been focussed on the interaction of environmental modifiers such as atmospheric chlorides, nitrogen oxides, sulfur oxides and wetting-drying cycles with materials on exposure. Previous studies and other observations indicate that these modifiers exert a stronger influence on deterioration than the commonly measured meteorological parameters.

(b) Limitations:

(i) No studies have been conducted with the purpose of relating these environmental modifiers to materiel item performance.

(ii) It is believed that part of the lack of ability to predict failures is due to the lack of understanding of environmental modifiers.

(c) Improvement:

(i) Precise measurement of environmental modifiers and their effects will provide the statistics to aid in time-to-failure prediction.

(ii) Precise measurement of environmental modifiers will enable more accurate definition of test sites and the mechanics of the deteriorative effects of each, giving better scientific basis to site selection for specific tests.

(d) Impact:

(i) A comprehensive test site definition would not be resolved.

(ii) Time-to-failure predictions will be made without sufficient scientific basis.

c. Dollar Savings.

Tangible dollar savings cannot be determined. The investigation is one more in a series directed toward solving the number one methodology problem at TTC--the means to interpret the tropic environment and predict its effects.

d. Workload.

Over the past eight (8) years the U. S. Army Tropic Test Center has experienced 61 tests directly pertinent to this investigation. The tests are shown below by test type:

PI	EDT	ST (DT-II)	SP	SS	CKT	Total
10	11	28	5	2	5	61

The results of this investigation can be applied to future surveillance and exposure tests. Shown are samples of applicable tests.

Item	FY	75	76	77	78
Armored Vehicle	All below are DT-II				
Launched Bridge			ST	ST	
Mine A7/AV Arty Delivered		ET			
M51 CB Shelter System		ES			
10 KW Turbo-Alternator		ST	ST		
Small Starlight Set (3R Gen)					ST

e. Association with Requirements Documents.

Requirements taken from specified requirements documents (SDR) are listed below:

(1) SDR for Remote Area Lightweight Multi-Weapons Armorer's Kit. "Be resistant to fungi, insects, mildew, corrosion moisture and vapor.""Be capable of safe storage (5 years) and transportation by individuals participating in missions within an Unconventional Warfare Operational Area under hot-dry, warm-wet, intermediate, and cold climate conditions, as defined in paragraph 7, Cl, AR 705-15."

(2) SDR for Army Aircraft Weapons Handling Equipment, Multipurpose. "Materials will be such as to provide maximum resistance to rust, corrosion and deterioration in service and prolonged storage." "Construction materials used will provide maximum resistance to harmful effects of rodents, fungi, humidity, rain, snow, salt, water, and wind and will have a useful life span of at least 10 years." "Paragraph 7, Cl, AR 705-15."

Exposure/Performance Tests of Selected Materiel Items - Continued

(3) SDR for Lightweight Camouflage Screening System. "Be resistant to mold, rot, fungus, corrosion, and color-fading."

(4) SDR for A Lightweight Decompression Chamber. "Construction materials used will provide maximum resistance to harmful effects of rodents, fungi, humidity, rain, snow, salt, water, and wind and will have a useful life span of at lest 10 years." "Paragraph 7, C1, AR 705-15."

f. Others. Not applicable

9. RESOURCES.

a. Financial

	Dollar (Thousands)	
	FY 75	
	In-house	Out-of-house
Personnel Compensation		
Permanent Full-time	12.9	
Part-time		
Travel	1.0	
Contractual Support		9.0
Consultant & Other Svcs		
Materials & Supplies	2.1	
Equipment		
G&A Costs	13.5	
Subtotals	29.5	9.0
FY Totals	38.5	

b. Explanation of Cost Categories.

(1) Personnel Compensation. N/A

(2) Travel. N/A

Exposure/Performance Tests of Selected Materiel Items - Continued

(3) Contractual Support. Contractual support is required to provide a field operations unit capability to assist in data collection, reduction, storage, and limited laboratory activities.

(4) Consultants or Other Services. N/A

(5) Materials & Supplies. N/A

(6) Equipment. N/A

(7) G&A Costs. G&A costs are computed at the rate of $11.50 per direct labor man-hours. This rate, provided by the TTC Budget Office, includes overhead and host-tenant support costs.

c. Obligation Plan.

	FQ	1	2	3	4	TOTAL
(Obligation Rate Thousands)		19.4	19.1			38.5

d. In-house Personnel.

(1)

	Number	Manhours FY 75 Required	Manhours FY 75 Available	Total Required
Materials Engr, GS-0806	1	500	500	500
Chemist, GS-1320	1	200	200	200
Chief Scientist, GS-0085	1	50	50	50
Rsch Engineer, GS-0801	1	50	50	50
Hydrologist, GS-1315	1	50	50	50
Rsch Meteorologist, GS-1340	1	50	50	50
Opns Rsch Analyst, GS-1515	1	150	150	150
Forester, GS-0460	1	50	50	50
Chem Test Off. (7360)	1	75	75	75
Total		1175	1175	1175

Exposure/Performance Tests of Selected Materiel Items - Continued

(2) Resolution of non-available personnel. N/A

10. INVESTIGATION SCHEDULE.

	FY 75
	J A S O N D J F M A M J
In-house	----------R
Contract	-----------
Consultants	-

11. ASSOCIATION WITH TOP PROGRAM. The results of this investigation, if definitive, will be used to develop a TOP entitled, "Tropic Exposure Considerations."

/s/Robert F. Callahan
/t/ROBERT F. CALLAHAN
COL, Armor
Commanding

(END COPY)

APPENDIX B. REFERENCES

1. Ball, R. W. Jr. "Tropic Integrated Engineering and Service Test of Tank, Collapsible, Self-Supporting, 5000-Barrel Capacity," TECOM Project No. 7-7-0887-05, US Army Tropic Test Center, Fort Clayton, CZ, March 1968, AD 832 124.

2. Downs, G. F, III and W. F Lawson III, "Determination of Optimum Tropic Storage and Exposure Sites, Report I: Survey of Programs in Tropic Materials Research," USATTC Report No. 7304001, TECOM Project No. 9-CO-009-000-006, US Army Tropic Test Center, Fort Clayton, CZ, April 1973, AD A 005016.

3. FF-B-187a. "Bearing, Roller, Tapered," Federal Specification, 1 July 1960.

4. Jesse, H. A., and C. H. R. Kramer. "Initial Production Test (Tropic) of Tank, Fabric Collapsible, 10,000 Gallon Capacity," USATTC Report No. 6907005, TECOM Project No. 7-ES-435-100-003 and 7-5-0562-13, US Army Tropic Test Center, Fort Clayton, CZ, July 1969, AD 858 731.

5. Johnson, M. A. and G. F. Downs III. "Methodology Investigation: Steel Corrosion in Tropic Mangrove Forests," USATTC Report No. 7511002, TECOM Project No. 7-CO-RD5-TT1-016, US Army Tropic Test Center, Fort Clayton, CZ, November 1975.

6. L-P-378C. "Plastic Sheet and Strip, Thin Gauge, Polyolefin" Federal Specification, 6 February 1967.

7. MIL-B-11040 C. "Belt, V: Engine Accessory Drive," Military Specification, 17 June 1966.

8. MIL-B-18D. "Batteries, Dry," Military Specification, 29 October 1963.

9. MIL-B-18/9B. "Battery, Dry, BA-30," Military Specification Sheet, 6 May 1965.

10. MIL-B-18/250 (EL). "Battery, Dry, BA-399/U," Military Specification Sheet, 26 February 1968.

11. MIL-B-18/251 (EL). "Battery, Dry, BA-505/U," Military Specification Sheet, 26 February 1968.

12. Ortiz, L. R. "Initial Production Tests of Tanks, 10,000-Gallon, Collapsible, POL," USATTC Report No. 7106002, TECOM Project No. 7-ES-435-100-012, US Army Tropic Test Center, Fort Clayton, CZ, June 1971, AD 885 776L.

13. Palumbo, N. W. "Product Improvement Test (Tropic) of Tank, Collapsible, 10,000-Gallon," USATTC Report No. 7208002, TECOM Project No. 7-ES-435-100-015, US Army Tropic Test Center, Fort Clayton, CZ, August 1972, AD 902 343L.

14. Portig, W. H., J. C. Bryan, and D. A. Dobbins. "Determination of Optimum Tropic Storage and Exosure Sites, Phase II: Patterns and Predictions of Tropic Materials Deterioration," USATTC Report No. 7405001, TECOM Project No. 9-CO-009-000-005, US Army Tropic Test Center, Fort Clayton, CZ, May 1974, AD A005018.

15. Portig, W. H., G. W. Gauger and G. F. Downs III, "An Intensive Approach to the Study of Materials Deterioration in the Tropics," paper presented at 8th Army Science Conference, West Point, NY, June 1972, AD 750366.

16. Sprouse, J. F., M. D. Neptune, and J. C. Bryan. "Determination of Optimum Tropic Storage and Exposure Sites, Report II: Empirical Data," USATTC Report No. 7403001, TECOM Project No. 9-CO-009-000-006, US Army Tropic Test Center, Fort Clayton, CZ, March 1974, AD A005017.

17. Stavinsha, L. L. and F. M. Newman. "The Isolation and Determination of Aromatics in Gasoline by Gas Chromatography," Final Report FLRL No. 13, US Army Coating and Chemical Laboratory, Aberdeen Proving Ground, MD, April 1972.

18. Stavinsha, L. L. and F. M. Newman. "Hydrocarbon Type Analysis of Gasoline by Gas Chromatography," Final Report FLRL No. 15, US Army Coating and Chemical Laboratory, Aberdeen Proving Ground, MD, July 1972.

19. TM 10-1105. "Inspecting and Testing Petroleum Products," Department of the Army Technical Manual.

20. TM 11-5820-549-12. "Operator and Organization Maintenance Manual: Receiving Set, Radio AN/PRR-9 and Transmitting Set, Radio AN/PRT-4," Department of the Army Technical Manual, 24 October 1966.

21. TM 11-6625-937-12. "Organizational Maintenance Manual: Indicator, Channel Alignment ID-1189/PR," Department of the Army Technical Manual, July 1967.

22. USATTC Letter Report. "Product Improvement Test (Tropic Storage) of Tank, Fabric, Collapsible, 10,000-Gallon Capacity," TECOM Project No. 7-5-0562-07, US Army Tropic Test Center, Fort Clayton, CZ, October 1968, AD 844 886L.

23. USATTC Letter Report. "Integrated Tropic Engineering and Service Test of Tank, Collapsible, Self-Supporting 1250 BBL Capacity," TECOM Project No. 7-4-0481-03, US Army Tropic Test Center, Fort Clayton, CZ, January 1967, AD 825 288L.

APPENDIX C. DISTRIBUTION

Exposure/Performance Tests of Selected Materiel Items

TECOM Project No. 7-CO-RD5-TT1-016

Addressee	Final Report
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Commander US Army Aircraft Development Test Activity Fort Rucker, AL 36362	1
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